(Crop Disease and Pest Series, No. 2.)

THE

AGRICULTURAL LEDGER.

1897—No. 16.

FUNGI.

(PUCCINIA, RUST.)

[*DICTIONARY OF ECONOMIC PRODUCTS, Vol. III., F. 725.*]

RUST IN WHEAT IN THE AUSTRALIAN COLONIES.

A précis of the Literature of the Australian Inter-Colonial Wheat Conferences, 1890-96; with comments on the bearing of the results obtained on Wheat-Culture in India. By SURGEON-MAJOR D. PRAIN, M.A., M.B., *Curator of the Herbarium, Royal Botanic Garden, Sibpur.*

Other DICTIONARY articles that may be consulted:

Agaricus, *Vol. I.*, A. 589-599.
Claviceps, *Vol. II.*, C. 1313.
Morchella, *Vol. V.*, M. 647.
Truffles, *Vol. VI., Pt. IV.*, T. 843.
Fungoid Blights, *see the articles under Coffee, Indigo, Papaver, Rice, Sorghum, Wheat, Tea, Zea, etc. Consult also the Agricultural Ledger No. 4 of 1893* (Potato Disease), *and No. 5 of 1893* (Vine Disease).

also

Agricultural Ledger No. 20 of 1895 (Indian Fungi).

CALCUTTA:
OFFICE OF THE SUPERINTENDENT, GOVERNMENT PRINTING, INDIA.
1897.

The objects of THE AGRICULTURAL LEDGER are—

(1) To provide information connected with agriculture or with economic products in a form which will admit of its ready transfer to ledgers;

(2) To secure the maintenance of uniform ledgers (on the plan of the Dictionary) in all offices concerned in agricultural subjects throughout India, so that references to ledger entries made in any report or publication may be readily utilised in all offices where ledgers are kept;

(3) To admit of the circulation, in convenient form, of information on any subject connected with agriculture or economic products to officials or other persons interested therein;

(4) To secure a connection between all papers of interest published on subjects relating to economic products, and the official Dictionary of Economic Products. With this object the information published in these ledgers will uniformly be given under the name and number of the Dictionary article which they more especially amplify. When the subject dealt with has not been taken up in the Dictionary, the position it very possibly would occupy in future issues of that work will be assigned to it.

PREFACE.

WITH the owner of a rusted wheat-field the question that arises is probably oftener "What can be done to prevent this loss?" that "What is the cause of this loss?" Yet to answer the first question satisfactorily, it is essential to begin by answering the second. Hence the arrangement that has been followed in digesting the information to be gleaned from the rust literature of Australia.

This treatment may strike the reader as incomplete. Besides those chapters that deal with the palliation and the avoidance of rust, why, it may be asked, is there no chapter dealing with "Rust-Eradication"? In theory, at all events, a rust should be harboured during the interval between one wheat-harvest and another on some other plant or plants. Discover such intermediate hosts, destroy them, and rust must disappear.

The omission is intentional. This method, in principle perfect, is at least in India inapplicable in practice. In the case of the majority of our Indian rusts, the intermediate hosts are unknown. In some, possibly in all, the existence of an intermediate host is not absolutely essential, other means of bridging the gap between one harvest and another having been evolved. There seems to be no doubt that in certain instances the occurrence of an intermediate host has ceased to be necessary for a rust, and there is reason to believe that the disease-germs are often practically inherent in certain wheats, intimately associated with the protoplasm of the plant and capable of continuing so for weeks or months or even years, only awaiting the advent of suitable conditions in order to dissociate themselves from the protoplasm. The partnership being thus dissolved, they may give rise to a general destructive outbreak of rust. Even in the case of that Indian rust where it seems possible that an intermediate host has been ascertained, the difficulties in the way of its eradication are so great as to render the proposal barely feasible.

Practically, therefore, the only hope for India in combatting rust in wheat is to adopt the method of selecting, from among the various kinds of wheat, those that show themselves to be naturally little liable to rust. For, while probably no wheat is absolutely immune, it is a recognised fact that in certain areas particular

wheats are relatively proof against rust. By a system of cross-breeding with kinds valuable on other accounts, new kinds can be made that will combine these qualities with the character of resistance to rust; by a further process of rigorous selection the characters of these improved kinds can be fixed under at least particular conditions and in, at all events, particular localities. If theoretically less perfect, this process is practically the sounder of the two, since it not only results in the production of wheats that resist infection from without and thus render the eradication of intermediate hosts unnecessary; it also eliminates those wheats in whose tissues the disease-germs are inherent—or, at any rate, gives us kinds wherein the fatal dissociation of the disease-germs from the protoplasm of the plant does not occur—and is thus successful in cases where the eradication of intermediate hosts must fail.

It has to be distinctly borne in mind that mere selection is rarely, if ever, sufficient. The quality of resistance to rust may be, and indeed usually is, associated with qualities that render the wheat, of which it is characteristic, otherwise undesirable. Cross-breeding, in order to associate with the resisting quality other qualities that are of importance, is, therefore, essential. The sowing of patches of this, that and another wheat and their examination during the course of a season may be useful as the basis of notes on the wheats available for experiment within particular provinces, but can do little towards a final solution of the problem before us.

This crossing of different wheats, though a *sine qua non*, is beset with many difficulties. Fortunately, however, for India these difficulties are being largely removed by the public spirit and energy of Mr. W. Farrer, of Lambrigg, New South Wales, the foremost exponent of this method of combatting rust. Mr. Farrer is placing at the disposal of the Government of India samples of crosses eminently suited for experimental culture in this country, since they combine with Indian blood—thus giving them the highest possible chance of becoming acclimatised—the blood of wheats especially characterised by the possession of the very features wherein it is known that Indian wheats are defective.

On the experts of the Agricultural Departments of the various wheat-growing provinces, therefore, devolves merely the duty of

applying to these samples the methods of selection prescribed by Mr. Farrer. But everything depends on the minute care with which these methods are applied. Mr. Farrer's recommendations, owing to their great importance, have been given in full as an Appendix (B); their perusal and adoption by those whose duty it may be to attempt to 'make' wheats that will resist the ravages of rust in India is essential. The mere sowing of Mr. Farrer's samples, in order that a record of their immunity or otherwise from rust may be recorded at the close of a season, by no means fulfils the requirements of the case. Only a small percentage of the plants raised from the first generation of Mr. Farrer's seed will supply material for further experiment; the fate of the remainder does not, therefore, interest us. The preparation of such a record implies that the object of the experiment has not been clearly understood; worse still, it may imply the waste of an opportunity and the loss of a season. To supply material whence a rust-resisting wheat may be hoped to be evolved and to receive in return no more than a barren report is to ask for bread and receive a stone.

On the other hand, it must be borne in mind that success is not to be hoped for in one season or in two; the process of evolving, of fixing, and of issuing for general use a rust-resisting wheat can only be a gradual one. Nor should it be supposed that the task of evolving a rust-resisting wheat can be completed once for all. Wheats appear to vary in character with time; wheats that prove rust-resistant and prolific in one area often fail in one or in both characters elsewhere; wheats immune as regards one rust frequently fall victims to another. This task of evolving and fixing rust-resisting wheats, once initiated, must be gone on with; continuity of policy and of effort are essential to its success. But from what may be deduced from the Australian literature here reviewed and digested, it seems not unreasonable to hope that, granted this continuity, a very decided degree of success may be attained in dealing with the rust problem.

HERBARIUM, DAVID PRAIN.
ROYAL BOTANIC GARDEN, SIBPUR;
October 9, 1897.

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CHAPTER I.—INTRODUCTION.

Explanatory.

§ 1. The writer, by desire of the Government of India in the Revenue and Agricultural Department, has read those papers dealing with the subject of Rust, and relating mainly to Australia, that are on the files of that Department. The following pages contain a *précis* of this information with occasional comments on its bearing upon wheat-culture in India, drawn up during moments of leisure from official duties.

History of the Inter-Colonial Wheat Conferences in Australia.

§ 2. The subject of rust has caused much anxiety to Australian wheat-growers; this anxiety has been shared by the Agricultural Departments of the Governments of the various Colonies, and has culminated in the elaboration of a concerted inter-colonial scheme for counteracting the effects and mitigating the ravages of the blight. The idea of conjoint investigation and action appears to have first occurred to, or at any rate to have been first convincingly advocated by, Mr. F. Wright, a South Australian gentleman who, at a meeting in Melbourne of the Australian Association for the Advancement of Science, proposed that a Committee of the Association be appointed for the investigation of rust in wheat with a view to remedying the evil.

A Committee was appointed, but came early to recognise that, if useful results were to be obtained, the assistance of Government must be invoked. This assistance was readily granted; but the intervention of Government made the

difficulties of working through a scattered Committee at once apparent. The idea of holding an inter-colonial conference was the natural sequel, and, in response to an invitation on the part of the Government of Victoria to the Governments of New South Wales, Queensland and South Australia to send delegates to Melbourne to meet delegates representing Victoria and discuss the Rust-problem, the "First Inter-Colonial Wheat-Rust Conference" was held at Melbourne on March 10th and 11th, 1890.

This Conference was followed by a "Second," held at Sydney on June 2nd-5th and June 8th, 1891; at this meeting the same Colonies were represented. A "Third" Conference was held at Adelaide on March 9th-12th, 1892; on this occasion Tasmania was represented in addition to the other Colonies mentioned. At the Adelaide meeting it was decided that in future the Conferences should be biennial; consequently the "Fourth" Conference, which was held at Brisbane, met in 1894 on March 20th and 21st, and March 26th-28th, while the "Fifth" Conference, which met at Melbourne, was held in May 1896.

Mode in which the results of the Conferences have been presented.

§ 3. The discussions at these Conferences mark the progress that has been made in Australia from 1890 to 1896 both as regards knowledge of Rust and as regards the best means of combatting it. The minutes of the various Conferences include, therefore, practically all that is to be learned on the subject; the somewhat numerous notes, papers, and reports that have appeared during the Conference period will be found on examination to consist for the most part of extracts from the minutes of a previous Conference or of statements of experience considered in due course at a subsequent one.

The single exception, and it is a formal rather than a material exception, consists of a series of "*Contributions to an economic knowledge of the Australian Rusts*," written by Dr. N. A. Cobb and published in the *Agricultural Gazette of New South Wales* at intervals during the period from December 1890 to April 1894. Dr. Cobb has been a delegate from New South Wales to the greater number of these Conferences, and has himself done much to make them successful. His "*Contributions*," therefore, add nothing to the sum of the information contained in the Conference minutes. They are, however, very valuable, because they treat from another standpoint, and arrange systematically, the facts that at the various conferences have been approached from the practical side and have had, of necessity, to be dealt with on empirical lines.

Literature reviewed.

§ 4. The literature here reviewed and digested may, therefore, be classified as :—

I.—Conference Literature; Reports of the various Australian Inter-Colonial Wheat-Rust Conferences.

II.—Inter-Conference Literature; Reports, Bulletins and Papers dealing with points referred to at a previous Conference or suggested for discussion at a subsequent one.

III.—Extra-Conference Literature; Dr. Cobb's "*Contributions*" published by the Government of New South Wales in its *Agricultural Gazette* during 1890—94.

To facilitate reference to the originals, a full list of the papers, classified in this way, is here given and, in subsequent chapters, papers of the various groups are referred to, shortly, as (I.) I Conf., II Conf., etc.; (II.) Sub-conf. A., B., C., and so on; (III.) Cobb. Contrib., the volume and page cited in the latter case being those of the New South Wales *Agricultural Gazette*.

§ 5. I.—CONFERENCE LITERATURE.

Reports of Australian Inter-Colonial Wheat-Rust Conferences.

1. Minutes of Proceedings at a Conference of delegates from Victoria, South Australia, New South Wales, and Queensland; held at Melbourne, March 10-11, 1890: *ref.* I Conf.

2. Report of the Proceedings of the Conference of delegates from Victoria, South Australia, New South Wales and Queensland; held at Sydney, June 2-5, and June 8, 1891: *ref.* II Conf.

3. Report of the Proceedings of the Conference of delegates from Victoria, South Australia, New South Wales, Queensland, and Tasmania; held at Adelaide, March 9-12, 1892: *ref.* III Conf.

4. Report of the Proceedings of the Conference of delegates from Victoria, South Australia, New South Wales, and Queensland; held at Brisbane, March 20, 21, and March 26-28, 1894: *ref.* IV Conf.

5. Final Report of Committee at the Conference of delegates held at Melbourne, May 1896 : *ref.* V Conf.

In order that a brief, yet clear, view may be had of what has been accomplished at *each* Conference, the Reports of the various Conferences in Committee are given in full as Appendix C.

§ 6. II.—INTER-CONFERENCE LITERATURE.

New South Wales.

A. 1891. Agricultural Gazette of New South Wales, vol. 2, part 7, page 403 (July 1891)—
Rust on Wheat Conference (second) *held at Sydney.*

B. 1892. Agricultural Gazette of New South Wales, vol. 3, part 3, page 221 (March 1892)—
Recommendations of the Conference (third) *held at Adelaide.*

C. 1892. Agricultural Gazette of New South Wales, vol. 3, part 7, page 481 (July 1892)—
Further References to the Recommendations of the Rust in Wheat Conference held at Adelaide in March 1892.

D. 1892. Agricultural Gazette of New South Wales, vol. 3, part 8, page 567 (August 1892)—
Rust-resisting Wheats.

E. 1893. Agricultural Gazette of New South Wales, vol. 4, part 7, page 598 (July 1893)—
Rust-resisting Wheats.

F. 1894. Agricultural Gazette of New South Wales, vol. 5, part 1, page 48 (January 1894)—
Rust-resisting Wheats.

G. 1895. Report regarding the working of Department of Agriculture, New South Wales, January 1894—July 1895, pages 25-28—
Experiments with Wheats.—Dr. Cobb.

H. 1897. Letter from W. Farrer, Esq., Lambrigg, Queanbeyan, N. S. W., to the Government of India, Department of Revenue and Agriculture (August 1897)—
Wheats likely to prove suitable for the Climate of India.

Tasmania.

I. 1892. Department of Agriculture, Tasmania; Bulletin n. 3—
On Rust in Wheat.—E. H. Thompson.

Queensland.

J. 1892. Department of Agriculture, Queensland; Bulletin n. 19—
On Wheat-growing in Queensland.—E. M. Shelton.

K. 1895. Department of Agriculture, Queensland; Bulletin n. 6 (second series)—
On Wheat-growing Experiments.—E. M. Shelton.

VICTORIA.

L. 1894. Department of Agriculture, Victoria—
Report on Wheat-Rust Experiments, 1892-93.—D. McAlpine.

NEW ZEALAND.

M. 1894. Second Report of Department of Agriculture, New Zealand, page 53—
Rust.

N. 1894. New Zealand Country Journal, vol. 18, No. 3, page 220—
Rust in Wheat.

O. 1895. New Zealand Country Journal, vol. 19, No. 5, page 493—
Experiments with Rust-preventing Manure at Lincoln College.

SOUTH AUSTRALIA.

P. 1896. Copy of Minute by the Secretary to the Agricultural Bureau, South Australia, dated Adelaide, May 8, 1896.

CANADA.

Q. 1896. Report on Wheat-Rust by the Director of the Experimental Farm in Canada.

Ref. SUB-CONF. A., B., etc. Owing to the fact that some of these notices are digests of Conference proceedings (*e.g.*, A. and N.) or *verbatim* extracts from Conference minutes (*e.g.*, B.); while still others (*e.g.*, D., E., F.) consist of information incorporated in the minutes of subsequent Conferences, it has not been necessary in every case to formally cite these papers in the chapters that follow.

Three Indian papers:—*Resolution on the Revenue Administration of the Central Provinces for the year* 1894-95; *Indian Fungi* (Agricultural Ledger, 1895, No. 20); and a *Report by the Commissioner of Settlements and Agriculture, Central Provinces, on the Cultivation of Cross-bred Wheat,* 1897; which the writer has likewise been directed to read in connection with this subject, belong in a fashion to this list; it has, however, seemed more convenient to keep them apart from the Colonial literature and to quote them separately.

§ 7. III.—EXTRA-CONFERENCE LITERATURE.

Contributions to an economic knowledge of the Australian

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Literature of Conferences.

Rusts. *By* N. A. Cobb. Published in the *Agricultural Gazette of New South Wales* in the following order :—

	Vol.	Part.	Page.	Date of Publication.
Introduction	1	3	185	Dec. 1890.
Chapter I.—Methods . . .	,,	,,	186	,, ,,
Chapter II.—Rusts that occur in and about Australian wheat-paddocks	1	3	197	,, ,,
Appendix A.—Details of experiments, etc., undertaken in order to learn what rusts occur in and around the wheat-paddocks in New South Wales . . .	,,	,,	203	,, ,,
Resumé	,,	,,	214	,, ,,
Chapter III.—What has been found out in this and other countries concerning wheat-rust . .	3	1	44	Jan. 1892.
Chapter IV.—The subject continued	,,	,,	52	,, ,,
Appendix B.—Report on the rustiness of wheats examined at Lambrigg	,,	,,	60	,, ,,
Alphabetical List of wheats examined at Lambrigg .	,,	,,	60	,, ,,
Chapter V.—The subject continued	,,	3	181	Mar. 1892.
Chapter VI.—An examination into the physical properties of Rust-Resistant and Non-Rust-Resistant wheats	,,	,,	190	,, ,,
Appendix C.—Measurements of the thickness of leaf (flag) in different varieties of wheat .	3	3	201	,, ,,
Appendix D.—Width of penultimate leaf at the middle . .	,,	,,	206	,, ,,
Appendix E.—Measurements of the tensile strength of the penultimate leaf of different varieties of wheat	,,	,,	207	,, ,,
Chapter VI (*bis*).—Varieties of wheat	4	6	431	June 1893.
Chapter VII.—Keeping seed-wheat true to name. Causes leading to mixed seed . .	,,	7	503	July 1893.
Chapter VIII.—The artificial cross-fertilizing of wheat . . .	,,	,,	506	,, ,,
Chapter IX.—Improving wheats by Selection. Experimental plots .	,,	,,	512	,, ,,
Chapter X.—The subject continued	5	4	239	Apl. 1894.
Chapter XI.—Harvesting experimental wheats . . .	,,	,,	251	,, ,,

It will be observed that two distinct "Contributions" are marked "Chapter VI." *Ref.* Cobb. Contrib. with vol. and page of *Gazette*.

To this class belong the majority of the European and American treatises and pamphlets that have been consulted in drawing up Chapter II; here again it has been more convenient to keep them apart from the Australian literature and, when necessary, to quote them separately.

Chapter II.—THE RUST-PROBLEM.

Damage from Rust.

§ 8. Addressing the delegates to the first Inter-Colonial Conference on Wheat-Rust in 1891, the Minister of Agriculture for Victoria put the loss from rust for the previous season at £1,500,000 sterling for South Australia alone, and appeared to think the loss in Victoria had been as great (I. Conf., p. 6).

The same season, evidently one in which Rust was particularly destructive, is independently calculated to have caused a loss of £2,370,000 sterling in Australia generally, and of about £30,000 in Tasmania (Sub-conf. I. 8).

The Committee appointed to draw up a series of Resolutions at the First Conference gave the estimated loss at £1,500,000 for South Australia, £750,000 for Victoria, £100,000 for New South Wales, £20,000 for Queensland. The total loss suffered was estimated at not far short of £2,500,000 sterling (II. Conf., p. 41).

In the Gippsland province of Victoria where, 35 years before, wheat was widely grown, it was stated in 1891 that its cultivation had for 30 years been largely abandoned owing to the ravages of rust (II. Conf., p. 13). As an instance of the losses caused by Rust, may be cited the experience of a South Australian gentleman. On one plot of 5,000 acres, farmed on metayage,—owner finding land and seed and taking $\frac{2}{5}$ths the produce, metayer finding labour and taking $\frac{3}{5}$ths,—the share of the former was estimated in October to be worth £5,000. The wheat was attacked by rust in November and yielded the owner nothing.

The loss in Victoria in 1889 ranged from 2 bushels and 10*s*. per acre to 20 bushels and £5 per acre (II. Conf., p. 16).

The Minister for Mines and Agriculture in New South Wales, addressing the delegates at the Second Conference, stated that, if only one or two bushels per acre of the wheat now destroyed by rust were saved to Australia, it would mean an addition of £100,000 annually to the national wealth.

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Anything *short* of eradication of rust must therefore still be of the greatest advantage (II. Conf., p. 2).

The sum mentioned must be an error of the printer for £1,000,000 or some similar figure. For if the average loss in South Australia be, as is stated (II. Conf., p. 50), 7—8 bushels per acre in rusty years, and if the rates quoted for Victoria are in any way applicable to the other Colonies, the gain in South Australia alone would be several millions sterling, since in 1892 the Minister of Agriculture and Education for South Australia was able to inform the delegates to the Third Conference that in 1891 there were 3,147,106 acres under wheat in the whole Colony. This was, moreover, the area actually reaped and did not include what, owing to its having been attacked by rust, was cut for hay (III. Conf., p. 9).

The Rust-disease is the only serious obstacle to the cultivation of wheat in Queensland. In 1889, of 15,861 acres only 2,700 acres were rust-free. The average yield per acre in rust-affected areas was 17 bushels, in rust-free areas 21 bushels. But these figures show only a small part of the total damage done, for no more than 7,504 acres were reaped as wheat; 7,326 acres,—or nearly half the total acreage—had to be reaped as hay so soon as the rust appeared (II. Conf., p. 29).

In New South Wales in 1891 the average loss per acre was a little over 2 bushels per acre: the total loss was 636,520 bushels (III. Conf., p. 13). In Victoria in 1891 only 109 acres had to be cut for hay, but in North Victoria the loss varied from 2-12 bushels per acre, in South Victoria from 2-10 bushels per acre (II. Conf., p. 18).

For India it is estimated that an annual loss of 10 per cent. is under rather than over the mark (*Agric. Ledger*, 1895, n. 20, p. 72).

Rusty Years.

§ 9. It is believed in Chili that the conditions which favour the appearance of rust recur regularly once in seven years (II. Conf. 47). In Australia a similar belief in a cycle of eleven years is indicated (II. Conf. 15).

Rust in Australia is undoubtedly much more prevalent in certain seasons than in others. These do not, however, display any periodicity, nor are they always common to the several Colonies. It is the general experience of Australian farmers that rust, in amount sufficient to do serious harm, does not often appear in two succeeding years (II. Conf. 15).

In South Australia rust has been known since 1851 and at short intervals has caused much loss (II. Conf. 50).

The year 1860 is mentioned as one in which the wheat crop was a total failure in New South Wales, whereas no mention is made of rust that year in Victoria. The years 1863 and 1864 are given as rusty years in Victoria, though, as a matter of fact, rust has been recorded for that Colony every year from 1862 onwards (II. Conf. 15). In 1867 it was almost general and caused immense loss in South Australia (II. Conf. 50). In 1875 there was much rust in Tasmania (II Conf. 23); 1878 was one of the worst years for rust in Victoria (II. Conf. 15), and in South Australia (II. Conf. 50) it prevailed over a considerable area that year. In South Australia 1880 was another year when a considerable area was affected. The seasons 1882—1888 seem to have been very free from rust, but 1889 was a year in which it was almost general and caused great loss in South Australia (II. Conf. 50), in Victoria (II. Conf. 15), in New South Wales (II. Conf. 32), and in Tasmania (III. Conf. 23). In 1890 it was again almost general throughout South Australia (II. Conf. 50); the year was not considered a "rusty" year in Victoria. In 1893-94 rust was prevalent in many parts of Wellington, N. Z. (Sub-conf. M. 53).

The experiences of 1867, 1878, and 1889 favour the theory of a cycle of eleven years (II. Conf. 15), but the facts against it are quite as weighty. [In any case the periodicity, supposing it to exist at all, is not due to any inherent property of rust, but must, as seems to be the belief in Chili, be the result of a recurrence of conditions favourable for its development.]

The Indian experience is parallel with the Australian.

Annoyance caused by Handling Rusted Wheat.

§ 10. An incidental effect of rust is the annoyance that is said to be caused by handling rusted wheat. It appears that on Darling Downs (Queensland) it is hard to obtain help to work wheat affected by rust. The men are said to develop large ulcers and sores, caused by working among rusty wheat (II. Conf. 38). In Victoria too there is said to be no doubt that the threshing of rusty wheat has caused ulcers among the men (II. Conf. 39).

There seems to be no reference to any such experience in India.

Natural History of Rust.

§ 11. Rust in wheat is due to the parasitic existence on the wheat plant of a fungus (*Puccinia*), which is normally of a polymorphous and of a heterœcious nature.

Both characters vary in extent in different *Puccinia*, but, as regards the better-known rusts affecting wheat, they

are limited as follows. The rusted wheat, when examined closely, is seen to derive its "rusty" appearance from the presence of red or brown pustules (*sori*) scattered over the flag, or at times also affecting the straw or even the ears. These vary in size from $\frac{1}{25}$ - $\frac{1}{5}$ of an inch long by $\frac{1}{75}$ of an inch wide, and in the majority of the wheat-rusts increase in size, so that the cuticle of the plant, which at first is continuous throughout, at length gives way over the site of each pustule.

The variation in size and shape is due to a tendency the pustules at times show to run together; this tendency is naturally influenced by the severity of the disease—which is in turn affected by the favourable or unfavourable character of the conditions in which the wheat grows; also, by the character of the tissues of the plant—which depends upon the variety of wheat, the age of the plant, and the part affected.

The contents of a rust-pustule, when closely examined, are found to be masses of minute red or brownish single-chambered oval bodies (*spores*) supported by fine transparent stalklets that in turn spring from an interlacing network of pellucid threadlets (*mycelium*) ramifying in the tissues of the plant. These ramifying fibres really constitute the parasite that lives upon the food-material elaborated by the wheat-plant for its own use; it is the appropriation of this elaborated matter by the fungus that starves the wheat-plant and leads to the "pinching" or total absence at the end of the season of the grain that this food-material would otherwise have gone to form. Once such a fibrous mycelium obtains a footing within a wheat-plant, it goes on growing till it forms a pustule, the spores inside which are bodies specially modified to assist in the perpetuation and reproduction of the fungus. When the pustule is ripe, the spores are shed as a small cloud of microscopic red dust. When the spores are carried to the leaves of still unaffected plants and the conditions as to warmth and moisture are suitable, the membrane enclosing each gives way at certain definite weaker points and the contents exude as a narrow thread-like stream that extends across the surface of the leaf on which it rests till its free end finds one of the breathing-pores (*stomata*) with which the surface of the leaf is studded. The thread now grows in through this *stoma;* once inside, it proceeds to absorb the nutrient juices of the plant, to grow vigorously and ramify in all directions, so producing a mycelium that goes on to the formation of pustules and spores as before. This stage of growth of the fungus is the *Uredo* stage, these red spores are termed *uredo-*

spores, and it is the phase of growth which is manifested by their production that is popularly known as *Rust*.

So long as the weather conditions are suitable and the wheat-plant holds out as a source of food, the fungus is believed to go on producing successive crops of rust-pustules and spores. But towards the end of summer a change usually takes place in the development of the fungus, and among the red pustules which rupture to let the spores escape, black ones, over which the cuticle of the plant often remains intact, begin to make their appearance. The presence of these black pustules gives rise to the naked-eye appearance of dark-grey to light-grey streaks on account of which this stage of the growth of the fungus is known popularly as *wheat-mildew*. The contents of a mildew-pustule are spores as before, but spores of a different kind. Instead of being one-celled, each is double, being divided across the middle; instead of germinating rapidly if, and perishing readily unless, they encounter suitable conditions, these black spores, as a rule, require to rest through the remainder of autumn and during the winter, and cannot germinate till the following spring. As they need this period of rest, and because they complete the growth of the fungus for the season, they are termed variously *resting spores*, or *teleutospores* (ending-spores). This mildew stage being, after a fashion, a concluding one, constitutes the *Puccinia* proper.

At the commencement of the following season these teleutospores germinate by the protrusion of their contents through a weak spot in the membrane just as happens with the uredospores. The subsequent growth and history is, however, different in the two cases. Instead of endeavouring to find its way within the tissues of some other plant, the thread remains exposed, branches but slightly, and at the tips of the branches it forms, simply by spontaneous separation (abjointing) and not by special formation of true spores, minute spore-like bodies that are carried away by the wind to germinate under favourable conditions on, and to penetrate and live parasitically within, the tissues of some other plant. The branching thread that issues from the teleutospore resembles, but still does not really constitute, a true mycelium; it is therefore termed a *pro-mycelium*, and the small bodies that behave like, though they differ in formation and structure from, true spores are termed *sporidia*.

On whatever plant these sporidia rest and germinate they give rise to a mycelium, the presence of which, in the majority of instances, causes swellings, generally of some fairly

bright colour, to appear in the tissues of the leaf of the host-plant. Embedded in this swelling are usually small cup-like bodies of different sizes; the smaller, termed *spermogonia*, contain cells termed *spermatia*, the object and nature of which are not precisely known; the larger, termed *æcidia*, contain yellow spores termed *æcidiospores* which are known to produce, in some cases at least, when they germinate under suitable conditions, a mycelium that produces rust-pustules of *uredospores*.

There are thus two stages, and four very distinct phases in the life of a fully developed *Puccinia* from teleutospore to teleutospore.

The first phase is the production of the *pro-mycelium* with the separation of its *sporidia*. This promycelial phase is characterised by being non-parasitic. The germination of its *sporidia* gives rise to a parasitic mycelium that produces the second or *æcidial* phase, which ends in the formation of special spores (*æcidiospores*). The production of these æcidiospores ends the æcidial stage of the life-history of the fungus, because the germination of these gives rise to a parasitic mycelium that produces throughout its existence successive crops of rust-pustules containing uredospores, and ends in the formation of resting-spores or teleutospores. The formation of these teleutospores ends the *puccinial* stage of the existence of the fungus; the two phases of this stage, the *uredosporic* and the *teleutosporic*, though practically successive, are organically simultaneous, since they are produced by the same mycelium, and thus differ from the two phases of the æcidial stage which are organically as well as chronologically successive.

There are two well-marked classes of *Puccinia*, those that are "autœcious" or that spend the *Puccinia* stage and the parasitic phase of the *æcidial* stage on the same host plant; and those that are "hetercœcious," and find it necessary that the two different mycelial stages shall live on and be nourished by different host-plants. The arrangement that ensures this result is exceedingly simple. In the first class the *sporidia* produced during the non-parasitic pro-mycelial phase are capable of germinating on the plant which carried the teleutospore that gave rise to the pro-mycelium. In the second class these sporidia cannot germinate on the plant that carried the teleutospores, but are only able to do so on some quite different species. Looking then at the formation of teleutospores as completing the round of existence of the fungus, and treating the formation of a pro-mycelium, with its resulting sporidia, by the germination of these teleutospores as the com-

mencement of a new round, we speak of the plant which carries the *Puccinia*,—that being differentiated by the characters of its teleutospores,—as a "host" of the fungus; in the case of a member of the second or "heterœcious" class, where the æcidial stage exists on a plant other than the one that carries the *Puccinia*, we speak of the plant on which the *æcidium* exists as an "intermediate host" of the fungus.

A characteristic feature of most, if not all, *Puccinieæ* is that they are restricted as to their habitat; a particular *Puccinia* is only met with on a particular host in the case of the autœcious ones and both the host and the intermediate host, which *must* themselves be different plants, may be equally particularised in the case of the heterœcious ones. It is, however, not usual, particularly in the case of the better known *Puccinieæ*, to find that either the *æcidial* or the *Puccinia* stage, even in the heterœcious class, is strictly limited to any one special plant; usually the fungus is to be found on a smaller or greater number of naturally closely allied plants; these then are "collateral" hosts. Sometimes indeed the same stage may occur on widely different plants; in such cases it is perhaps usual to find that one or other of these is affected by only one phase of that stage.

Finally, it must not be overlooked that both stages are not in all cases known; it seems, indeed, likely that the two are not in every case necessary. Thus *Æcidia* are known and described, the corresponding *Puccinieæ* of which are at least as yet undiscovered. There seems reason to suspect that in some of these cases the *Puccinia* has disappeared, and that the æcidial stage has come to be able to perpetuate itself directly. This stage is not, however, in any case a cereal blight, and the matter does not therefore directly concern us. What is of practical moment is the fact that the æcidial stage of certain *Puccinieæ* is unknown; perhaps even is non-existent, either from never having been evolved or from having become unnecessary. Hypothetically there are three possible explanations of the absence of the æcidial stage of a *Puccinia*:—

(1) Perhaps it does occur but has not yet been discovered. Possibly this is even true of many cases where there is direct evidence that the stage is not absolutely essential.

(2) A frequently advocated theory is that the *sporidia* produced by the pro-mycelia to which the germinating teleutospores give rise, while retaining the power of developing on the "intermediate host"

into a mycelium which produces æcidia, acquire also the power of developing on the "host" into a mycelium which produces uredospores and teleutospores (CONF. I., 51; SUB-CONF. L. 29). This hypothesis has never been confirmed by any competent observer.

(3) The third explanation is that the blight can dispense in certain cases, and at least for a time, with its æcidial stage owing to the resting phase (*teleutospores*) of the *Puccinia* stage never requiring to come into play, the active phase (*uredospores*) of this *Puccinia* stage being able in these cases to produce successive crops throughout the year. The "collateral" hosts of the *Puccinia* are not necessarily contemporaneous species; one may be coming into vigorous growth as another is dying down. Oftener still, while one may, like a cereal crop, be annual, and thus on being reaped cease for a period of months to be a possible host for the blight, another in all likelihood is some perennial grass on which the blight may exist and may form successive crops of uredospores during the interval between the cereal crops of two succeeding seasons. This, too, may happen without the collateral host in question being seriously inconvenienced; a "rust" that under certain conditions is almost fatal to a particular crop, may be present on another plant without doing it, even under the same conditions, any great harm. This hypothesis is hardly more satisfactory than the preceding one. Far from spreading freely from one collateral host to another, the same rust invariably shows the utmost disinclination to pass even from one race to another of the same collateral host. This has been shown by careful experiment in America (*Kansas Expt. Station*, Bull. n. 46, p. 4) and in Europe (APPEND. A., p. 71).

Rust in Europe.

§ 12. Rust to the farmer is more or less of a simple entity, and is supposed by him in Britain to consist at most of but two sorts, the spring and the summer rusts respectively, the former appearing in the period from March to May and doing little damage as compared with the latter, which does not usually appear till June or July. The experience of the continent appears to be somewhat the reverse; there the earlier or spring rust seems to be, as a rule, the more harmful.

The opinion of the practical agriculturist has carried perhaps a little too much weight with the botanical student for, though it has been fairly apparent that there are really more than two forms of rust affecting the cereal crops in Europe, these forms have been all set down as particular manifestations or conditions, at very outside as mere varieties of one or other of these two. The spring-rust has been identified, as a rule, with *Puccinia rubigo-vera*, a species of which the hosts were supposed to be RYE and WHEAT and a number of wild grasses, while the intermediate hosts were said to be certain Borages (a couple of Alkanets and a Bugloss). The summer-rust has been identified with *Puccinia graminis*, a species the hosts of which are a crowd of wild grasses and all the common cereals, the intermediate hosts being a number of species of Barberry. Besides the "Wheat-Barberry" and the "Wheat-Borage" rust there was, however, admittedly a "Wheat-Buckthorn" rust, *Puccinia coronata*, with its hosts, as before, a number of grasses and its intermediate hosts several of the Buckthorns.

In America this "Wheat-Buckthorn" rust appears to be a subject that calls for serious practical consideration. In Australia it is not known to occur at all; in Asia and in Europe it does not occur on wheat. That attention should have been mainly confined in Europe to the other two was not therefore unreasonable.

The treatment they have received has not, however, been altogether accurate. Practically the natural limits of "Summer" or "Wheat-Barberry" rust have been found to agree with the *Puccinia graminis* of botanical works, though it appears that a quite distinct rust, which occurs only on "Timothy-grass" and does not affect wheat, has been confused with it. The "Yellow Spring" rust has, however, been much confused. Practically the typical form has been naturally enough defined in books, so far as the *Uredo-Puccinia* stage is concerned. But it is found that the idea that the *æcidial* stage of "Yellow Spring" rust occurs on any "Borage" is erroneous. The æcidial stage and the intermediate host of the common "Yellow Spring" rust are unknown, and the æcidium referred to as occurring on the two Alkanets belongs to a quite different rust, the "Brown" rust. Under the name of *Puccinia rubigo-vera* or "Spring" rust, two different rusts have thus been included, *viz.*:—

(1) "Yellow" Rust (*Puccinia glumarum*) of which the intermediate host and the *æcidium* have not been found or do not exist, and

(2) "Brown" Rust (*Puccinia dispersa*) which is alone entitled to be termed the "Wheat-Borage" rust, since it has an *æcidium* that occurs on various Borages. At the same time the *Puccinia* usually referred to in books as a variety (VAR. *simplex*) of *Puccinia rubigo-vera*, turns out to be quite distinct from "Yellow" and from "Brown" rust alike. As in the case of "Yellow" rust, its æcidial stage and its intermediate host or hosts are unknown.

In the most exhaustive work on European Rusts, *Die Getreideroste*—by Messrs. Eriksson and Henning, who have for several years been engaged in studying practically the subject of rust on behalf of the Government of Sweden—an enumeration of these rusts and of their hosts is given. The following are the salient facts in this list:—

1. PUCCINIA GRAMINIS, or BLACK RUST, occurs, in Scandinavia alone, in its *æcidial* stage on 5 species of Barberry and in the *Uredo-Puccinia* stage on 107 different grasses including OATS, BARLEY, RYE and WHEAT, and under wheat, on common wheat, hard wheat and 'spelt' alike. Outside Scandinavia the *æcidial* stage has been found on 8 other species of Barberry and the *Uredo-Puccinia* stage on 43 other grasses.

There are thus no fewer than 150 known collateral hosts for the Black-rust and 13 collateral intermediate hosts for its æcidial stage. That these figures are not exhaustive is very probable seeing that in other countries the search for it has not hitherto been so systematic as that instituted in Sweden. That this particular rust spreads as *Uredo* on cereal crops by reason of its being harboured by Barberry bushes in the *æcidial* stage has been repeatedly demonstrated. But that the passage through this æcidial stage is only occasionally, if indeed it ever be, essential is equally evident since outbreaks of rust have over and over occurred where it was impossible to trace the attack to the presence of the æcidium on Barberry bushes, or indeed to find any Barberry bushes that could harbour the æcidium. In other places, too, the complete eradication of Barberries, which in theory ought to have exterminated the blight, has in practice failed to do so. Yet, in spite of the extraordinary number of grasses that harbour the blight in the stage which is harmful to cereals, and enables it to tide over the interval between two cereal crops on one or other of its collateral hosts, as von Tubeuf and others have again and again found that it actually does, it is remark-

able that it does not make use of its opportunities. On the contrary, the forms of the rust affecting the four cereal crops are as distinct physiologically as if they were different species (APPEND. A., p. 70).

The most important observation from the Indian point of view that has been made in Europe, is that *Puccinia graminis* occurs on RICE in Italy. It is not said sensibly to affect the rice crop, but if it exists on rice at all, it would be quite easy to account for the existence of this particular rust in India throughout the year without any change of host or of stage being called for. But, as will be shown presently, the Rust which in India is taken to be *Puccinia graminis* may not be that species, and in any case the probabilities are against the *immediate* infection of the one crop by the other.

2. PUCCINIA PHLEI-PRATENSIS, or "TIMOTHY-GRASS" RUST, which Eriksson and Henning separate off from 'Black Rust,' occurs only on Timothy-grass (*Phleum pratense*) in the *Uredo-puccinia* stage, and, so far as is known, affects no cereal crop. Its æcidial stage is unknown and is perhaps non-existent.

3. PUCCINIA GLUMARUM, or "YELLOW" RUST, is the next important rust that is dealt with by Eriksson and Henning. Its æcidial stage is quite unknown and is perhaps non-existent. In Sweden the *Uredo-Puccinia* stage has been found on 15 grasses, including RYE and WHEAT, under the latter on common, hard and 'spelt' alike. It has not been met with on barley. Outside Sweden it has been met with, for certain, on one other grass; and assuming, from the descriptions and measurements given, that certain (perhaps the majority) of the cases of occurrence of *Puccinia rubigo-vera* refer really to *P. glumarum*, Eriksson and Henning conclude that it is borne by 38 other grasses, including OATS. There are thus probably 54 collateral hosts of this *Puccinia*.

The *P. rubigo-vera* of Australian writers is, according to Eriksson and Henning, this species. They do not, however, suggest that the so-called *P. rubigo-vera* of Indian authors is to be referred here, and in this, as will be seen presently, they are probably quite justified.

4. PUCCINIA DISPERSA, OR "BROWN" RUST, is the third important rust that Eriksson and Henning give.

This occurs in Sweden in the *æcidial* stage on two of the Alkanets and in the *Uredo-Puccinia* stage on 11 grasses, including RYE and WHEAT, both common wheat and 'spelt.'

This is the true 'Wheat-Borage' Rust of Sweden and probably is the 'Wheat-Borage' Rust of other countries also. As

yet, however, no list of collateral hosts is available beyond the limits of Sweden. There is no evidence that this rust occurs at all in Australia, and there is every reason for believing that it does not occur in India (*Agric. Ledg.*, 1895, n. 20, p. 46).

5. PUCCINIA SIMPLEX, or "PIGMY" RUST, another rust enumerated, is not very important. Its *æcidial* stage and intermediate host, if it has such, are not yet known, and as an *Uredo-Puccinia* it only occurs on Barley.

This has often been treated as a mere variety of '*P. rubigo-vera*,' but it seems to be quite distinct, and in any case when one considers that *P. rubigo-vera* has hitherto been a confused entity, it is better kept apart.

There is no evidence that this occurs in Australia, and an Indian rust which Dr. Cunningham and the writer have suggested the necessity for comparing with this one (*Rec. Bot. Surv. Ind.* I., 121) turns out, now that an accurate account of *P. simplex* is available, to be quite different.

6. PUCCINIA CORONATA, or "CROWN" RUST, is the last rust described in Eriksson and Henning's work. This occurs in Sweden in the *æcidial* stage on three species of Buckthorn and in the *Uredo-Puccinia* stage on seven different grasses, one of these being OATS. Outside Sweden its *æcidium* has been found on nine other Buckthorns (one of these being an Indian one) as well as on a *Berchemia*, a plant very closely allied to the Buckthorns. Its *Uredo-Puccinia* stage, outside Sweden, has been found on 42 different grasses, including BARLEY (both in Europe and America); RYE and WHEAT (on the last two in America only, so far as is hitherto known).

This *Puccinia* has thus 49 known collateral hosts, and of these four are Indian, with 13 collateral intermediate hosts.

But though it attacks most, if not all, the common cereal crops in America, it has in Europe, outside Sweden, only been found on BARLEY, there apparently doing no serious harm. In Asia it has not been found to attack our cereal crops, and in Australia it is apparently unknown.

Rust in Australia.

§ 13. As regards Australia, we find that in 1890 Dr. Cobb examined 124 specimens gathered from different parts of New South Wales. Of these, 6 were the rust identified in Australia with *Puccinia graminis*, 2 were *Puccinia poarum*, 102 were the "*Puccinia rubigo-vera*" of Australian writers, and 4 belonged to an undetermined species of *Puccinia*; the remaining 10 were miscellaneous.

Puccinia poarum was found on "Meadow grass" (*Poa annua*) only; of the examples of "*P. graminis*" one was on

wild oats, two were on oats, one on Barley and two on Wheat.

Of the "*Puccinia rubigo-vera*" examined, 94 were on wheat, two on oats, four on barley, one on rye-grass. Of the undetermined *Puccinia*, one was on wheat, two were on a native grass (*Deyeuxia Forsterii*), and one was on *Bromus mollis* (an introduced grass).

Considering wheat alone; of 97 rusted wheats, 94 were attacked by *Puccinia rubigo-vera*, two by *P. graminis*, and one by the undetermined species. The conclusion arrived at, therefore, is that Australian wheats are subject to three rusts, and that of these three the rust which did practically all the damage in 1890, was the rust identified as *Puccinia rubigo-vera*. But Dr. Cobb expressly points out that his investigations refer only to one season and only to that part of it up to November 6. He does not conclude that the results for another season need be the same (COBB, CONTRIB., vol. I., p. 214).

At the Second Conference also Dr. Cobb expressed his opinion that it is their "Spring-rust" (the supposed *Puccinia rubigo-vera*) that did most damage in New South Wales. It was supposed that in 1889 the destructive rust which attacked oats, barley, rye and some other grasses, besides wheat, was "Summer-Rust" (*P. graminis*), since the rust appeared in long lines, not in spots; in ordinary seasons (as in 1890) it is "spring-rust" that does most harm. This rust affects chiefly the flag, less often the straw (II. CONF. 34). It may be found all the year round on self-sown wheat, oats, or barley, and on certain wild grasses, and can pass from these to the wheat crop, the *uredo*-stage being continuous throughout the year whether the rust be "spring-rust" or "summer rust" (II. CONF. 37, 50; III. CONF. 29). The spores, moreover, may be twenty days in water and yet not lose their germinating power, so that they may exist occasionally in the soil for sufficient time to bridge over accidental gaps in the chain of collateral hosts (II. CONF. 34). Mr. McAlpine, however, states that he had failed up to 1891 to find any of the grasses mentioned as collateral hosts affected by either of the wheat-rusts (II. CONF. 16).

If "summer-rust" were the most destructive rust, then early sowing would be a great remedy since the wheat would be ripe ere the rust appeared. At the same time, Dr. Cobb advocates early sowing in spite of the apparent suggestion of a doubt as to its efficacy (II. CONF. 35).

Mr. McAlpine's experience in Victoria is that it is the

summer-rust (*P. graminis*) that is most injurious (SUB-CONF. L. 27) ; of 36 varieties of wheat examined by him, only one was free from rust and only one was affected by *P. rubigo-vera* ; all the others were attacked by *P. graminis* (III. CONF. 68). It is, however, fairly certain that in nearly all the years characterised as rusty, early-sown wheat has suffered badly from rust (IV. CONF. 20), an experience that certainly indirectly favours Dr. Cobb's judgment. But Mr. Farrer thinks the fact that most of the wheats said to be "rust-proof" nevertheless suffer badly from "*Puccinia rubigo-vera*" and are more or less resistant only to *P. graminis*, is important as involving popular recognition of the truth that *P. graminis* does most damage in Australia (III. CONF. 36 ; SUB-CONF. H. 4). And when the early rust ("*P. rubigo-vera*") is apparently very bad, it is not really that which does the harm ; it passes off, but *P. graminis*, which comes on later, destroys the crop.

In dealing with this aspect of the question Mr. Farrer objected to the seasonal distinction of name between these two rusts as not quite appropriate for Australia, or at all events for New South Wales. Mr. Farrer proposed the names "spotted-rust" for the earlier, and "streaky-rust" for the later, owing to the pustules being scattered in the former, and often confluent in the latter. His proposal did not, however, meet with approval, because "spottiness" and "streakiness" were not considered characteristic of the rusts by the other delegates. One Victoria delegate disliked the idea of any change of name. However, the President of the Third Conference at Adelaide pointed out that the term "summer-rust" in particular is not a good name in South Australia owing to the seasonal peculiarities of the Colony. Mr. McAlpine (Victoria), who objected to Mr. Farrer's names because streaky-rust is always spotted in its early stages and so might be mistaken for the other, prefers to term the spring or spotting or small rust the "yellow" rust, and the streaky or summer or common rust the "orange-red" rust. These are, no doubt, better names.

It is with the latter,—which Mr. McAlpine says is known everywhere to botanists as *P. graminis*,—that the farmer has mainly to deal. The former, which is known as "*P. rubigo-vera*," though claimed as commonest in New South Wales, is not so in Victoria, any more than Plowright has found it to be in England or than Galloway has found it in the United States (SUB-CONF. L. 27 ; II. CONF. 17). Dr. Cobb, however, who at most only pointed out that this rust was the commoner in New South Wales during the early part of 1890,

says that both are destructive to wheat in Australia (III. Conf. 29); doubtless this is the true state of affairs.

At the Second Conference one delegate, quoting from a South Australian report, said it had been noticed that in some localities red-rust appeared before the humid weather of September and October; in other localities, towards the south-east, after the dry hot weather had set in. The earlier rust is known popularly as "long-corn" rust and appears to have borne its full share with the "true" rust in destroying the harvest (II. Conf. 48). In this report the later rust is termed "vera rubigo," evidently from some confusion of thought as regards the name of one of the rust-fungi. The particular fungus thought of—*P. rubigo-vera*—is, however, an early, not a late, "rust." Fortunately the name, which is thus shown to be capable of misleading, does not any longer require to be used. The "yellow" and the "orange-red" rusts, according to McAlpine, both produce *teleutospores* in Australia towards the end of summer (they may even be met with in December—Australian mid-summer), or in the early autumn. But "corn-mildew", as this stage of the blight is termed in England, or "black-rust" as Mr. McAlpine prefers to term it,* does not seem to be so prevalent with the Australian rusts as with the corresponding English ones. These *teleutospores* only give rise to *sporidia* that, *ex hypothesi*, are incapable of germinating save on those plants that act as intermediate hosts. As regards the "orange-red" rust, which Mr. McAlpine identifies with *Puccinia graminis*, this would, were the determination correct, imply the power of germinating only on a *Barberry*. But no Barberry is wild in Victoria and none are grown to an appreciable extent; it is, therefore, says McAlpine, asserted that this phase of the rust is gradually dwindling away in Australia, from its being not only of no advantage to the species but rather a waste of energy to produce *teleutospores*. This is the hypothesis favoured by those who, while believing that the most destructive Australian rust is *Puccinia graminis*, decline to accept without direct proof the statement that its *teleutospores* can produce *sporidia* capable of germinating anywhere except on an intermediate host (Sub-conf. L. 28).

In Australia, however, Mr. McAlpine states, there are those who believe that the *teleutospores* of this "orange-red" rust, supposed by him to be *P. graminis*, produce *sporidia* that

* A somewhat unfortunate selection of name on Mr. McAlpine's part, because "Black-rust" is the general term throughout Europe for the rust which is known as *Puccinia graminis*.

can germinate on, and reproduce the red-rust in, the growing wheat of the next season.

As a practical matter, Mr. McAlpine considers both theories, and is himself inclined to think from his own personal observation and from what old farmers have told him, that the "black rust" (meaning by this the teleutosporic stage of the "orange-red" rust) is dying out considerably, the explanation being that the fungus, owing to the comparative absence of the Barberries required as intermediate hosts, is ceasing to produce *teleutospores* (Sub-Conf. L. 29). [It should be observed, however, that Mr. McAlpine gives no information as to the number of seasons that he has made this point a subject of personal observation, and does not explain the standard of comparison employed in coming to this conclusion.]

The other hypothesis, that *teleutospores* are *not* disappearing, but have acquired the habit of producing *sporidia* that can germinate on wheat, has also received Mr. McAlpine's attention. On this point "all that can be said at present is that wheat-plants infected with germinating teleutospores during the past season (1892-93) developed the red rust *earlier* than those growing alongside of them" (Sub-conf. L. 29).

Dr. Cobb (New South Wales), during the discussion at the Second Conference, while admitting the connection between *Puccinia graminis* and the Barberry plant, said that its *æcidium* had not, so far as he knew, been found in Australia, but that in any case "*it is not true that the Barberry stage is necessary in Australia for the production of* P. graminis." As to *P. rubigo-vera*, Dr. Cobb added, it exists all the year round, even in Europe, in the red-rust stage (II. Conf. 37). He does not, however, mention any experimental proof that in Australia it can pass to wheat from any of its collateral hosts; the evidence from America and from Europe is altogether against this being usual. In New Zealand, as in Australia, experience seems to throw doubt on the necessity for an æcidial stage in the rust supposed to be *P. graminis* (Sub-conf. M. 54).

It will be seen that, so far as Australia is concerned, there are two important and dangerous rusts, one a "yellow" or "spotted" early rust which has been identified with *Puccinia rubigo-vera*, another a later "orange-red" or "streaky" rust which has been identified with *Puccinia graminis*. It will be noted also that, while both are admittedly serious rusts, there is not perfect unanimity as to which is the more destructive. The balance of opinion is in favour of the later rust being the

more fatal in ordinary seasons; in very rusty years the balance of evidence, as presented by the Australian literature on the subject, is in favour of the early rust being the more dangerous. It will be noted, moreover, that, according to Eriksson and Henning, the most competent judges on this point, there is no such rust as *Puccinia rubigo-vera*. They seem to consider the early Australian rust identical with the European *P. glumarum*, for which no intermediate host is known, even in Europe. And it may be pointed out that there is every probability that the later rust, which Australian authors identify with *P. graminis*, is not that species either. The metric characters given by Dr. Cobb (Cobb, Contrib., vol. I., pp. 201, 202) for the Australian *P. graminis* certainly can hardly be said to deviate markedly from those given by Eriksson and Henning for the European one. But the very considerable limits of variation :—

Uredospores	European . . .	17—40 × 14—22 μ.
	Australian . . .	30—40 × 18—22 μ.
Teleutospores	European . . .	35—60 × 12—22 μ.
	Australian . . .	35—65 × 15—20 μ.

will lead even those unfamiliar with the subject of *Puccinia* to be unwilling to admit that measurements alone are sufficient to warrant the conclusion that the two are necessarily specifically identical. This feeling of doubt is not decreased by Dr. Cobb's observation that now and then, in the Australian *P. graminis*, he has seen pustules " in which all the *uredospores* appeared almost as if two-celled " (Cobb, Contrib., vol. I., p. 201), and his statement that he finds on a native Australian grass (*Agropyrum scabrum*), a rust which is absolutely identical with the Australian *P. graminis* as to structure, " if we except this difference that among its red-rust spots there are certain black bodies which may constitute a fourth spore of the rust." Dr. Cobb recognises the fact that this may show that the rust on *Agropyrum* is different from that on the wheat, and the point had not been experimentally tested when the statement was made (II. Conf. 34). It also leads to a desire for experimental trial as regards the supposed *P. graminis* itself.

This experimental test has been apparently applied. Mr. McAlpine says that " having determined the kind of rust affecting the wheat plots to be *Puccinia graminis*, the next point to settle was if it would affect the Barberry when sown upon it, as it is asserted to do in Europe and America." Taking *teleutospores* which, on being tested, were found to germinate, Mr. McAlpine proceeded to inoculate plants of four different

species of Barberry, at least two of which are known to carry the æcidial stage of *P. graminis*. The experiment in one case was conducted under a bell-jar; Mr. McAlpine does not say which of the four species tested was so treated. "The plants were carefully watched and tended, but no result appeared" (SUB-CONF. L. 30). Mr. McAlpine, it must be admitted, draws no express conclusion from this experiment. What conclusion he expected to be able to draw is not altogether clear. Since it happens that the power which its *teleutospores* have of producing *sporidia* that can germinate on certain Barberries is one of the diagnostic characters of *Puccinia graminis*, one might have expected the settlement of the point to have preceded any absolute determination of the species. Mr. McAlpine is content to reverse the process; the result of his test is, however, to lead the ordinary mind to suspend its judgment as to the identity of the "orange-red" Australian rust with the European *P. graminis*. The identity of the two has certainly not been made out, and so far as the evidence of Australian authors goes, is not highly probable.

Rust in India.

§ 14. The Indian rusts on cereals have not, like the European, American and Australian rusts, been made the subject of detailed study, prolonged over five or six seasons by capable and competent observers, specially deputed for the purpose. Consequently less is known regarding them. As in the case of Australia, however, it has been customary to suppose that there are two principal rusts, one of these being identified with the European *P. graminis*, the other with the confused and indeed non-existent *P. rubigo-vera* (*Agricult. Ledger*, 1895, No. 20, pp. 36, 45); *Puccinia coronata*, though known to occur in India, has not been found on any cereal crop.

As a matter of fact, there are in India at least four very distinct rusts on wheat alone with another that has so far only been found on barley. These are briefly described in a Note published in the *Records of the Botanical Survey of India* (vol. I., pp. 99—124) in 1896. In that note any attempt at identifying them with European rusts has been sedulously avoided and names have been given them merely with reference to the places where they were first seen during a tour undertaken in search of wheat-rusts.

One of these, termed the "Mozufferpur Rust," had some of the features of *P. graminis* for which it is usually taken and under which name it is included in Dr. Watt's review of Indian fungi. The structural and metric characters of the

"Mozufferpur Rust" do not, however, quite agree with those of *P. graminis*, the latter in particular having a much more limited range of variation. The pustules are differently disposed, and it is notable that, though it affected both wheat and barley as *P. graminis* does, it did so equally, whereas *P. graminis* is less severe on barley than on wheat; at the same time, this Indian rust left oats untouched, whereas *P. graminis* appears on that crop also. This last feature would render it equally doubtful if the Australian *P. graminis* be the same as this Indian rust. The æcidial stage of this Mozufferpur Rust has not been found.

Another, the "Ferozepur Rust," has all the characters that are credited in botanical works to "*P. rubigo-vera*," that is to say, to the *Puccinia*-stage of *P. glumarum*. And it is now less improbable that this rust *is* the same as the European one; the great difficulty hitherto has been the absence of its æcidial stage from any of the Indian Borages (*Agricult. Ledger*, 1895, n. 20, p. 46). As Eriksson and Henning now are able to tell us that its connection with any borage is probably an illusion, and that even in Europe the rust either does not have, or does not necessarily require to pass through, an æcidial stage, it is far from unlikely that the "Ferozepur Rust" may turn out to be *Puccinia glumarum*. But if this be so, and if this be therefore the *P. rubigo-vera* of most European and Australian writers, it must be recollected that it is not, or is only very partially, the *P. rubigo-vera* of Indian authors.

Both these rusts are probably of heterœcious type; that is, they either have an æcidial stage on an intermediate host or can dispense with the intermediate stage. At any rate, they both have teleutospores on wheat. For what seemed another form of the "Ferozepur Rust" from Lahore this is not absolutely clear, since no teleutospores were found; it may, however, only have been that they had not yet had time to appear. This "Lahore Rust" showed the further peculiarity of possessing two differently coloured and differently sized series of *uredospores*.

Another wheat-rust, "Saharanpur Rust," had no teleutospores, though it does not follow that it never has any. Its pustules appear to be somewhat like those of an unnamed Australian *Puccinia* on wheat (Cobb, Contrib., vol. I., p. 202), and though the measurements of the spores hardly agree, it must be recollected that Dr. Cobb's measurements were probably made from fresh material, while those of the Indian rust were made from specimens collected some time before.

A barley-rust, termed the "Mogul Serai Rust" in the

paper referred to, is there compared with what had hitherto been a doubtful European rust (*P. simplex*) referred by many authors to "*P. rubigo-vera*;" the appearance, since the *Note* was issued, of Eriksson and Henning's full account of this European rust makes it probable that the two are distinct; they agree in being apparently confined to barley; they differ, however, very considerably as regards size of *uredospores*. The *teleutospores* of "Mogul Serai" rust are not yet known; nor is its æcidial stage, if it has such.

The last and apparently by far the most important Indian rust is one described in the *Note* referred to as "Shibpur Rust." It seems to be this that usually does most harm in India, and it is this that, as a rule, is referred to by Indian authors as "*Puccinia rubigo-vera*." All the other European, Australian or Indian rusts are, or may be, of the hetercœcious class; this seems to be one of the autœcious class of *Puccinia*, or one of those that require no intermediate host, because their *æcidia* are carried by the same host as carries their *uredospores* and *teleutospores*. Only *uredospores* of this have been found on wheat, and it is as certain as any fact dependent on negative evidence ever can be, that it does not form teleutospores on wheat at all. All that affects the wheat in this case, therefore, is the *uredo*-phase of the *Puccinia*-stage of a rust that does not appear to be distinguishable from one, both the stages and all three parasitic phases of which occur together on a common Composite weed, *Launea asplenifolia*. As this weed has a perennial rootstock of considerable dimensions, the necessity for the formation of teleutospores does not at first sight seem evident. The plant possesses, however, the peculiarity of being absolutely leafless from June to October, throughout the whole rainy season in fact, and as the mycelium of the fungus has not been found to be able to penetrate the tissues of the rootstock, the formation of resting spores seems essential to its continuance. In this case, therefore, the appearance of the *uredo*-phase on wheat is an accident so far as the life-history of the fungus itself is concerned; it is, however, an accident that in certain seasons and under conditions suitable for the spread of the fungus is most detrimental to the wheat-crop.

The belief is fairly general that rust attacks other plants besides wheat. Thus it is reported that in South Australia "marsh-mallows" carry rust (II. Conf. 50). They do so certainly, but the rust on marsh-mallow has nothing to do with the rust on wheat (III. Conf. 17). Flax too is badly rusted in Australia, but not by the wheat-rust (II. Conf. 16).

The same is the experience in India. In the *Resolution on the Revenue Administration of the Central Provinces* for 1894-95, the Deputy Commissioner of Jubbulpore is quoted (p. 2) as follows :—" The cloudy and damp weather induced a very severe attack of our old enemy, red-rust. This appeared, as usual, in linseed first, and then spread to wheat." As the Chief Commissioner points out, on the next page, " the fungoid disease which attacked the linseed was distinct from that which attacked wheat. It was a common thing to see stray wheat-plants unaffected in a reddened linseed-field, and *vice versâ* a solitary linseed-plant in a wheat-field was found to be the only plant affected." The rust on linseed is a *Melampsora*, not a *Puccinia* (*Agricult. Ledger*, 1895, n. 20, p. 101).

Rust in America.

§ 15. In America it is stated that a wheat-rust, said to be "*Puccinia rubigo-vera*," and which may or may not be *P. glumarum*, passes the winter in the tissues of the wheat-plant in a mycelial condition ; the warm weather of spring induces a crop of spores which may, under favourable conditions, spread the disease ; the infection of winter-wheat is materially aided by " volunteer," or self-sown wheat, which carries the rust through the few months following harvest ; finally, that the red-rust spores are capable of maintaining their power of germination through the winter, and thus of infecting the crop in the following spring (*Agricult. Ledger*, 1895, n. 20, p. 55). Granting that these results are satisfactorily proven, they are not of practical moment for us in India. We have no wheat in the plains in the hot-weather and rains corresponding to winter-wheat in America, we have no volunteer wheat capable of bridging the gap between the harvesting of wheat at the beginning of the hot-weather and the sowing of the next crop at the end of the rains ; finally, we know that the red-rust spores of the Indian rusts, so far from maintaining their power of germination for several months, lose them in from 24 to 36 hours (*Rec. Bot. Surv. India*, I. 117). The facts in Europe accord with those in America, though the American explanation does not suffice to account for them ; *no mycelium is to be found in the tissues of the wheat-plant in winter* (APPEND. A., p. 76). In America, as in Australia, it is stated that the earlier rust does little harm ; the later rust is said to be the dangerous one (SUB-CONF. H. 4).

Time of Appearance of Rust.

§ 16. The time of appearance of rust varies in different districts and indeed does so in different years for the same district, the state of the weather hastening or retarding its appearance. The dangerous season in Victoria is generally given

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as from the beginning of October to early November (II. Conf. 15). This applies to Southern Victoria; in the northern districts November-December is the month (III. Conf. 17). The dangerous period is sometimes set down as extending over six weeks (II. Conf. 15).

The month of October is the critical time in New South Wales (II. Conf. 32). It is usually first observed in October, November or December, especially October and November (III. Conf. 14). The earlier the attack the more serious it is, since it is probable that at first only the lowest leaves are affected; if wheat has got beyond the flowering stage and the rust remains confined to the flag, the farmer is assured of obtaining a crop, though, of course, a less valuable one than in a non-rusty year (II. Conf. 36).

In South Australia the experience is that rust is generally first noticed about or shortly after the wheat comes into flower (II. Conf. 50). This is noted in other Colonies also, *e.g.*, Victoria (II. Conf. 17), and New South Wales (II. Conf. 32).

It is believed, and very probably justly so, that on going through any wheat crop at any season of almost any year and in almost any district, specks of rust may be found. All that is required for a general spread is a suitable condition of weather. The "breaking-out" of rust noticed by a farmer is probably *never the first breaking-out* (II. Conf. 37).

In spite of the nature of the facts it is said that many Australian farmers do not believe that rust is infective, but assert, on the contrary, that it *never* spreads. One Victorian farmer is quoted as basing his belief that this is so on the fact that in a particular season he had 60 acres of oats rusted, while 50 acres of wheat adjoining were free, "the oats receiving heavy rain while in blossom, while the wheat received the moisture when required—just before it burst into ear." This instance is commented on by Mr. McAlpine (Victoria) as follows:—"Here we have an illustration of rust not spreading, for the simple reason that the conditions were favourable to its spread in the one case (oats) and unfavourable in the other (wheat)" (II. Conf. 16). [It is of course equally possible that the rust which affected the oats may have been one that does not affect wheat at all; in any case, it is interesting to find that this popular belief is probably more correct than the opinion put forward by many trained observers.]

The Victorian experience is that the time which elapses between the first attack and the "spread" of rust averages from 12-15 days (III. Conf. 17), but in South Australia, and pro-

bably elsewhere, it has been found, when the conditions are favourable, to spread continuously from its first appearance (II. Conf. 50).

The accepted view of the Australian delegates is that, though undoubtedly infective, rust is not in any degree hereditary (II. Conf. 21); the view expressed by Eriksson, in the latest contribution to the literature of rust, is practically the reverse (Append. A, p. 75): the facts of the case, it must be admitted, are all in favour of the European observer's view.

The experience in India agrees very closely with that in Australia; sometimes the wheat is attacked by rust when it has little more than appeared above-ground—at other times not until it has almost or quite come into bloom. In the same season, too, it may be prevalent in particular districts and not in others. Thus in 1894-95, when it was prevalent in the Central Provinces, it was a noticeable feature of the season as well as of its predecessor that the damage by rust grew greater the further up the Nerbadda Valley one proceeded (*Resolution* on *Rev. Admin., C. P.*, p. 2). In 1895-96 rust was prevalent in Bengal and Tirhut, but could not be found in South Behar, the Central Provinces, Central India or Rajputana; it occurred, but was not severe, in the Punjab, but was not to be met with in Oudh (*Rec. Bot. Surv. India*, vol. I., No. 7).

Secondary Causes of Rust.

§ 17. It is evident from what is said in the preceding paragraphs that until the life-history of each of the wheat-rusts, in all the countries where wheat is grown, has been precisely ascertained, there is little hope of being able to prevent rust by the eradication of the blight itself. If, indeed, the latest theory of rust be accepted, its eradication seems impossible. Attention must therefore be directed to the secondary or mediate causes of rust—the conditions, inherent or accidental, that render wheat liable to rust. For the factors that increase the susceptibility to rust may be said to be of two kinds: those characteristic of the plant, those induced by its environment. The former are generally supposed to include a soft succulent condition of the tissues at the period when the rust-spores are abroad. This condition may of course be inherent in the variety of wheat which will consequently deserve to be classed as a "rust-liable" variety, or it may be induced by the environment—by the presence of moisture in the soil and the other conditions going to make a "rusty locality" as well as by the occurrence of a moist and still atmosphere accompanied by heat, these being the factors that go to make "rusty weather" and to induce a "rusty season." The most recent

experience, however, goes to show that the influence of at least two of these factors,—the state of the tissues and the circumstances of the environment,—have been exaggerated and misunderstood (APPEND. A., p. 74).

Varieties with little silicon in their composition are always prone to rust (II. CONF. 42). But even varieties naturally well-protected are liable if caught at a susceptible stage; this all the more readily if they be growing in a rich soil and so showing a broad and heavy foliage. For the broad and heavy flag required in England to evaporate as much moisture and to give as much exposure to sunlight as is possible in a climate so gloomy and so damp, is not advisable in a sunny climate like that of Australia. It does no good in ordinary seasons, and is a source of danger in rusty ones (II. CONF. 42). Moist and cloudy weather is apt to induce in any variety these undesirable characters; the want of sunshine diminishes the vigour of the plant, while the dampness increases the growth of leaf. There is more infective surface and at the same time less power to resist the infection (II. CONF. 32).

Wheats with a spreading flag are more liable to infection than those with an erect leaf (III. CONF. 35); as are those with a green foliage and unprotected by a waxy bloom.

Harvests in which rust has been bad have, generally in South Australia, been late ones (II. CONF. 50), and late maturity in a variety of wheat is exceedingly apt to expose it to infection by rust (II. CONF. 42).

In India it has been observed that those wheats with a soft starchy grain appear to suffer more from rust than those with a hard glutinous grain, as do those that have a broad leaf as opposed to those with a narrow flag. But perhaps neither of these characters is altogether directly responsible for the liability; those wheats that ripened late, however, very evidently suffered most (*Rec. Bot. Surv. Ind.* I., p. 101).

An insect related to the Hessian fly, when in the larval stage, is found in New South Wales to *feed on* the rust spores. It, however, also spreads the spores and so does more harm than good. By the Agricultural Department of the Government of New South Wales it is thought that this insect is responsible "for a very large amount of loss to the country by assisting the spread of the rust-fungus" (II. CONF. 35).

The subject of self-sown or "volunteer" wheat as a mediate cause of rust in the regular crop has been somewhat fully discussed at the Australian Conferences. In Australia there is no doubt that a self-sown crop may be rusty, but the

experience of some Victorian farmers is that any grains that drop from the harvesting and come up the following year, lie exposed, grow with the early rains and, if not killed in cultivating, are much more forward than sown grain and are rarely affected with rust (II. Conf. 22). This is the experience that accords with expectation and that is in line with the recommendation to sow early, in order that rust may be avoided—sowing too soon being a much safer error to commit than sowing too late (II. Conf. 10).

In Queensland, however, it is found that "volunteer" wheat is particularly liable to rust (Sub-Conf. J. 15), and a more recent census of opinion in Victoria has brought out the fact that, of 32 cases, the majority found self-sown wheat more rusty than ordinary wheat, while 9 found it to appear earlier on the self-sown than on the ordinary kind (III. Conf. 20). There is thus no doubt a risk attaching to the presence of self-sown plants. There is said to be little doubt that the presence of self-sown wheat is one of the factors enabling the *uredo*-stage of wheat-rust to be continuous throughout the year between one wheat crop and another (III. Conf. 29). It is, therefore, very advisable to keep down all self-sown wheat by means of sheep (III. Conf. 21).

The subject of volunteer wheat is not one that is likely to be of practical interest in India, for it may be doubted if any plants are likely to germinate; or, should they do so, to survive through the hot-weather that immediately succeeds the wheat harvest.

The two chapters that follow will be found to deal with these mediate causes of rust; it has seemed more convenient to reverse the order indicated in the paragraphs immediately preceding this, and to deal first with the accidental causes and with the remedies for those that have from time to time been tried.

Chapter III.—RUST-PALLIATION.

Rusty weather.

§ 18. Rust is usually most prevalent in seasons when the rain-fall is excessive, especially during October and November (II. Conf. 17, 49), and particularly if the wet season follows a warm spring (II. Conf. 50). Mere excess of rain-fall is not, however, sufficient to induce rust; it depends on the weather that follows (II. Conf. 47; III. Conf. 14). If clear weather, as is usual in Queensland, succeeds the summer rains, rust does not occur (II. Conf. 47). When close, damp, muggy weather sets in, then rust is certain to appear (II. Conf. 17, 28, 32, 47, 50);

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III. Conf. 14); it spreads most rapidly in calm hot days and dewy foggy nights (II. Conf. 17, 28), its progress being especially rapid if a heavy dew at day-break is followed by a hot sun (II. Conf. 46).

A dry cold season in Queensland is inimical to rust (II. Conf. 26), and a good high wind, especially a dry north one, is supposed at times to save the crop in Victoria (II. Conf. 17). In Queensland the belief is that rust appears during or after a thunderstorm; if this be followed by a westerly wind, the rust makes no headway (II. Conf. 28).

The year 1889, which was a very rusty one, was marked in New South Wales by frequent thunderstorms at the time the wheat was in bloom (II. Conf. 32). The colder districts were in that year less rusty than the others (II. Conf. 33).

A heavy downpour of rain is supposed to enable wheat to throw off rust. This is not, however, always the result; in any case the farmer's opinion that the rust has been washed away does not accurately represent what has happened. The mere fall of rain cannot wash out the fungus within the tissues of the plant, and could hardly arrest its growth. Perhaps the result of the rain-fall is to induce a sudden increase in the growing energy of the wheat-plant and to alter the conditions favourable to the growth of the parasitic fungus that constitutes rust. Perhaps, too, the lower temperature that often accompanies a fall of rain may help to check the growth of the rust (II. Conf. 17) just as hot, muggy weather favours its spread. In the same way, too, hot, muggy weather appears to change the character of the culm, and renders it liable to be attacked as well as the leaves; if only the flag be attacked, the grain is not ruined; if the stem also suffer, the grain does not form (II. Conf. 32).

Rust is said always to be worst in sheltered spots where the soil is damp, where mist lodges and currents of air do not readily reach the crop (II Conf. 19), and in particular districts particular exposures are said to be more affected by rust than others. In other districts some exposures, for instance, a seaward aspect with the concomitant influence of sea-winds, are said to be inimical to rust (II. Conf. 50). But no particular exposure or elevation, and no particular prevailing wind, confers complete immunity (II. Conf. 17, 19).

It is supposed in Victoria that, if January and February be wet, rust is inevitable, and it is recorded that at least one farmer advocates that no crop be put in if the apple-trees blossom in those months (Sub-conf. L. 39).

In India, also, rust is favoured by cloudy and damp weather

(*Resol. Rev. Admin., C. P.*, p. 2) or by sultry weather with an overcast sky (*Rep. by Commis. Settlement & Agriculture, C. P., on cross-bread Wheats*, 1897, p. 2) or by heavy morning fogs followed by heat (*Rec. Bot. Surv. Ind.* I. p. 82); the opinion of the Commissioner of Settlements and Agriculture, C. P., was that in 1897, after the sky became clear, the spread of the rust spores was checked by the strong sunshine.

Rust and Drainage.

§ 19. The question of moisture in the soil has been debated at some length. Rust is always said to be worst in hollows where water lodges (II. Conf. 19), and drainage is said to be perhaps the most important measure the farmer can take to mitigate rust; undrained land is always moist, and in some cases is the only kind at all affected. This is the opinion and general experience in Victoria (II. Conf. 18, 21), South Australia,—though there drainage is hardly practicable (II. Conf. 47, 50), and New South Wales (III. Conf. 15). It is, however, recorded that, although drainage, when its effect was experimentally tested in Victoria, induced a higher outturn it did not appear to affect the rustiness (II. Conf. 8), and when the experiment was repeated it was found that of six places artificially drained, five were rusty.

Dry or Damp Seed-bed.

§20. The experience as regards seed-bed seems equally variable. A dry seed-bed is strongly recommended in Victoria by all who refer to the subject,—sowing on a dry bed meaning, it is said, comparative freedom from rust, sowing on a moist seed-bed greater liability to affection (II. Conf. 16). In Queensland, on the whole, a dry seed-bed is supposed to be helpful as an escape from rust; why, Mr. Shelton, the Government Instructor in Agriculture, is not prepared to say,—if indeed it be true at all (Sub-conf. J. 15). Farmers who are of this opinion prefer to sow at once after ploughing, if the condition of the soil be otherwise favourable, and trust to rain coming to start the seed. But in Queensland some farmers decline to put their seed in a dry bed, preferring to wait for a shower, so as to ensure germination. Moreover, in some soils, where the land breaks up rough, the farmer prefers to wait for rain to enable him to harrow and pulverize the clods and so get a more even seed-bed (II. Conf. 28).

Rust and Irrigation.

21. The question of irrigation is also an important one. At an Irrigation Conference held at Melbourne in 1890, it was considered [probably by those in favour of irrigation, as such] that irrigated crops were not more affected by rust than unirrigated. The experience of others in Victoria has been that there was some rust on irrigated crops when there was none

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on unirrigated, and that rust was always worst on land irrigated during very hot weather (II. Conf. 18, 19).

It is stated also that in South Australia if a plot of land be heavily watered in the middle of summer and another plot be left unwatered, wheat sown in the watered plot will have much rust, wheat sown in the other will have little (II. Conf. 47). It would seem then as if irrigation were accompanied by drawbacks whether applied before or during the time the crop is in the ground.

Mr. Shelton (Queensland), speaking of his experience in Colorado, where he had himself been a wheat-grower and where, with a rainfall of only 10 inches *per annum*, every thing had to be irrigated, says he never saw or heard of rust there (II. Conf. 47).

It would appear that mere moisture in the soil is not enough to cause rust. Thus Mr. Kelly (South Australia) gives an instance of 10 acres of wheat, which was irrigated twice, yet showed no rust. "No rain fell on that wheat." He cites also the experience of wheat-growers in Chili where the crop is raised entirely by irrigation with snow-water and there is no rain. The soil is saturated fortnightly in this way, yet as a rule there is no rust. In certain years, however, the air becomes humid; the irrigating water is neither completely absorbed by the soil nor completely evaporated, but lies about in pools. When this continues for any length of time, rust appears. In 1862, a year of this kind, one farmer who abstained from irrigating saved his crop while his neighbours had theirs rusted (II. Conf. 47).

Mr. Pearson (Victoria) gives probably a sound opinion when he says that, while it may be true that sometimes irrigated wheat is freest from rust, at others suffers most, there is no doubt that irrigation judiciously applied is beneficial (II. Conf. 47). Indeed, Mr. McAlpine (Victoria) at the following Conference made the definite statement that irrigation applied early in the season does the crop good, and does not induce rust, though, if applied when the wheat is in flower, it causes very bad rust (III. Conf. 19).

The experience in the Central Provinces in 1897 with cross-bred wheats that were expected to be rust-resistant was that they suffered from rust. This was suspected to be partly due to the necessity there was for irrigation, owing to the abnormal dryness of the season and the soil. Water was applied seven times up to March 6th, the last application was made though the plants were not in need of irrigation, in order to discover

whether watering encouraged the rust-spores to spread. In the event it was observed that rust did spread to a certain extent (*Rep. by Commiss. Settlements and Agric., C. P., on Cross-bred Wheats*, 1897, p. 2).

Rust and soils.

§ 22. According to the Australian farmer crops on rich soils suffer most from rust (II. Conf. 17, 82); fallow-land being usually most affected (II. Conf. 19). This is the general experience in South Australia, and in rusty years the best crops have in many cases been reaped from the poorest soils or from exhausted fields (II. Conf. 49). One observer, however, thinks wheat should never follow wheat (II. Conf. 21). Light limestone and sandy soils always suffer less than loams and clays (II. Conf. 50).

In New South Wales clay surface and a clay sub-soil are bad because of the tendency to rust (III. Conf. 15); in Victoria the experience is that loam, clay or strong land suffer least; next comes a sandy soil; black soils suffer most, though chocolate soils are almost as bad (III. Conf. 19).

The explanation is obviously not the result of any *direct* connection between rich soil and rust. Rich soils and fallow lands naturally yield heavier crops; heavier crops mean more luxuriant vegetation, therefore softer tissues, and, as a consequence, greater susceptibility to the infection (II. Conf. 19, 49). In keeping with this is the experience in South Australia that rust is worst in those years when the crop is otherwise best (II. Conf. 50). The objection to wheat following wheat is the possibility of self-sown wheat plants appearing in the interval between the two crops and harbouring the rust in the meantime; such plants, termed "volunteers," are said to be particularly liable to be affected (Sub.-conf. J. 15). In Queensland wheat on scrub-lands is said to be particularly liable to rust (Sub.-Conf. J. 14).

Rust-free areas.

§ 23. In notoriously rusty districts in Queensland certain areas are never damaged by rust (II. Conf. 28) Their existence is not explained by Mr. Shelton, who called attention to them at the Second Conference, although they formed the subject of a prolonged discussion (II. Conf. 30, 31). The phenomenon appears to be undoubted.

The Mallee districts of Victoria are said also to be peculiarly rust-free, and so are the Murray Flats in South Australia; the explanation given of the comparative immunity from rust in these areas is that the crop ripens early—harvest beginning in October—and that the rain-fall is light. It is, however, contended that the phenomenon in Queensland is,

of a character that neither light rain-fall nor early growth will satisfactorily account for. It is true that in Victoria and elsewhere in any season one field may be found free from rust and an adjacent one be badly affected, and that the circumstance may be explicable owing to differences of local conditions as to drainage, position as regards wind, etc. But the point as regards these areas in Queensland is that even in rusty districts, and even on low-lying and black soils the crops in these rust-free fields growing beside and reaped along with rusty crops, *always remained rust-free* (II. Conf. 31).

Rust and cultivation; Ploughing.

§ 24. Intimately connected with this is the question of the treatment to which the soil is subjected beforehand. The effects of ploughing—deep as opposed to shallow—are doubtful. In Victoria both were found, in experimental observations, to be equally rusty; the deeply ploughed gave the heavier crop, thus favouring the development of rust indirectly (II. Conf. 8). Still in Victoria a general census of farming opinion showed that it was supposed in that colony that shallow-ploughing favoured rust (II. Conf. 18). In South Australia, on the other hand, deep-cultivation was supposed to favour rust (II. Conf. 50); when the facts were looked into it appeared that deep-ploughing was really not so good; at all events the average depth of ploughing, in lands reported rusty during 1891-92, was 6½ inches, the average depth in rust-free lands only 5½ inches (II. Conf. 14). But in the same year in Victoria the results were so evenly balanced (III. Conf. 19) that it is doubtful if they had anything to do withthe question; it is admitted, however, that the statistics and experiments recorded are not quite conclusive (II. Conf. 18; III. Conf. 48).

Harrowing the standing crop.

Harrowing when the plant was 2 feet high is reported in one case to have been followed by improved yield of grain "and the crop was very slightly affected by rust" (II. Conf. 21). [It does not follow that the freedom from rust depended on the harrowing.]

Rotation.

Rotation of crops is strongly recommended by Dr. Cobb. The reason why wheat gets diseased, if grown continuously in one place, is two-fold:—

(1) The soil is exhausted of those constituents that wheat specially draws upon.

(2) The enemies of wheat, at first few in a new country, year by year increase unchecked. Rotation, or a careful system of fallowing, will tend to check the proneness to increase of these enemies, and among them of rusts.

No method of combatting rust is more rational, therefore, than rotation (Cobb. Contrib. vol. 3, p. 183). This is more or less advocated by others (II. Conf. 21), Mr. Pearson (Victoria) thinking that for his colony the time for a general adoption of rotation has already arrived (II. Conf. 38). Indeed rotation is recommended because fallow-wheat and wheat after green-crop is said to be less rusty than wheat after wheat (II. Conf. 30, 33). It appears, indeed, that particular rotations are advisable; it is stated that wheat after mangolds proved more free from rust, less flaggy, stronger in the straw, less lodged and altogether a better crop than after potatoes (III. Conf. 45). In any case it is recommended that a field in which rust has appeared in one year should be left fallow the next (II. Conf. 33). One New South Wales farmer adds that wheat should not be sown too soon after ploughing; the delay, he thinks, gives a harder and more healthy straw (II. Conf. 33).

There is, however, another side to the question. Mr. McAlpine (Victoria) finds the results from rotation in Victoria very inconclusive (III. Conf. 19). In South Australia—where at present wheat is sown in fallowed land, the stubble is eaten off by sheep, in the following season the land is well worked, and wheat is again put in (II. Conf. 45)—it is found that high farming and rich soil operate in increasing the liability to rust, always supposing that the climatic conditions favour its development (II. Conf. 50).

Rust prevails with all kinds of cropping but seems to be always worst when the cultivation is good. Thus Mr. Lowrie (South Australia) finds that in the Experimental Farm at Roseworthy, well-tilled, well-manured, well-rested and new lands suffer most. Low-lying, rich or fertile flats are quite the worst, but new lands and manured fields also suffer badly (II. Conf. 50).

Fallowing.

In Victoria it was found in 1891 that fallow land was not more rusty than old land; while it did not seem that cropping any number of years added to the risk of rust (III. Conf. 19).

The opinion regarding fallowing is, in South Australia, divided; some advocate, others condemn the system. Mr. Lowrie thinks that the apparent exemption from rust which fallow-land in some cases enjoys is due to its being the custom to sow bare fallow-land first in the season and the crop is raised and ripened sufficiently early to escape the rust. On the other hand, wheat after wheat, being presumably more

dwarf and stunted than wheat after fallow, would suffer less from rust than the luxuriant crop after fallow if the two are sown together and are equally exposed to infection (II. Conf. 50).

Mr. McAlpine (Victoria) in giving a summary of recommendations (III. Conf. 21) advises working the land dry, cultivating deeply, draining thoroughly and sowing seed in a dry bed.

Mr. Bayne (New Zealand) also advocates good agricultural methods as the best means of combatting rust, among these being clean culture, judicious rotations and fallowing of land (Sub-conf. O. 493)

Burning Stubble.

§ 25. Whether the stubble should be burned before wheat is put in, is a much-discussed point. One observer strongly advises it (II Conf. 21) as a wise precaution since it destroys any spores of rust that may be about. It will not, however, be fully effective unless the weeds that may harbour the rust in adjacent paddocks and along headlands are rooted out and burned also.

In Queensland only about 20 per cent. of the farmers had experience of the treatment. Those who have tried it favour it (II. Conf. 28), and it is officially recommended (II. Conf. 30) for the Colony.

In New South Wales the results and opinions are rather contradictory (II. Conf. 32) and not much is known about it (III. Conf. 15). Some of the farmers recommend it; so does Dr. Cobb (II. Conf. 33, 35). Mr. Farrer (New South Wales), on the contrary, is much opposed to it owing to the waste of humus-forming matter (II. Conf. 40); to this Mr. Pearson (Victoria) replies that while this is true, it is better to sacrifice the humus and avoid the risk of losing 50 per cent. of the wheat-crop, if keeping the stubble means harbouring the spores of rust (II. Conf. 44). Mr. Shelton (Queensland) too, while agreeing with Mr. Farrer that it is inadvisable to burn "straw" (after the stripper), thinks there is no harm in burning "stubble" (after the reaper) for at best the stubble is rough and is not a good fertilizing material (II. Conf. 45). On reconsideration Mr. Farrer was prepared to permit the burning of stubble if done immediately after harvesting and if followed by a catch crop of cow-peas (II. Conf. 41, foot-note).

In experiments conducted at Port Fairy (Victoria), it was found that a plot where the stubble had been burned bore a heavier crop and was less affected by rust, and this, although it was *on the sheltered side of a fence* (II. Conf. 8), and there-

fore in other respects less favourably situated. But later evidence from Victoria was decidedly against the burning of stubble being of the faintest use (III. Conf. 20), and this is the South Australian experience also (II. Conf. 51).

In South Australia there was many years ago a law preventing the burning of stubble and in those days the crops of wheat were excellent; at that time, however, the farmers knew nothing about rust (II. Conf. 45).

Manures.

§ 26. Besides the mere physical treatment of the soil, the question of special applications, including, of course, manures proper, has also been carefully considered at these Conferences.

Of manures proper, farm-yard manure almost always gives the worst results. In Victoria the crop on patches experimentally grown with farm-yard manure was sickly from the first (II. Conf. 7). In New South Wales also, farm-yard manure produced a flaggy, much-rusted crop (II. Conf. 33); the same was the experience in South Australia (II. Conf. 50). In Queensland little manure is used, that little being mostly farm-yard, and it did not seem to have any bad effect; it was, however, admitted that the year under discussion (1890) was a year of little rust in any case (II. Conf. 28). It is not, however, in Queensland alone that the ill-effect of stable-litter and farm-yard manure is denied (II. Conf. 18), but the evidence against its use is fairly strong, for 24 out of 31 of those who used it report badly of it. The rusting is evidently not a direct result of the application of manure, but is induced because the manure promotes a rank growth and a tendency to lodge (itself an indication that the straw is weak), and thus prevents the free passage of air among the straw (II. Conf. 7; III. Conf. 42). The rank growth, moreover, causes delay in ripening, which is also a factor increasing the risk of rust (Sub-conf. J. 15).

Nitrogenous manures have been found in South Australia to favour rust, while phosphatic ones rather tend to diminish it. (Mr. Lowrie, III. Conf. 65). In New South Wales, Mr. Anderson states that phosphatic manures ripened the wheat 10–14 days earlier and such crops were doubled (III. Conf. 68). The explanation, cited from Voelcker, is that nitrogenous manures by affording the plants an excess of nitrogenous food retard the ripening of corn crops, whereas phosphate of lime, often present in considerable quantity after a mangold crop, has a tendency to induce early maturity (III. Conf. 67).

This acceleration of ripening helps to save the crop from rust (SUB-CONF. J. 15).

A year earlier, however, Mr. Lowrie had found experimentally that both phosphatic and nitrogenous mixtures decidedly increased the tendency to rust (II. CONF. 50), while the experimental results recorded from Victoria in two successive seasons showed pretty conclusively that plots where wheat was grown with phosphates were more rusty than those grown without phosphates or without manure at all. At the same time the use of nitrogenous manures did not appreciably increase the amount of rust (II. CONF. 7; III. CONF. 42). The explanation given by Mr. Pearson (Victoria) of these results was that probably the effect was indirect; the thinner, poorer crop resulting from the absence of manures afforded better ventilation to the plants, and the better ventilation of a thin crop *in Australia* favours freedom from rust. If the contention that nitrogenous manures increase rust be a sound one, the result is no doubt due to the unusually thick crop produced (II. CONF. 7).

Mr. Shelton (Queensland) was, however, unconvinced by the Victoria results, since in Queensland plots that had received no fertilizing agent were just as variable in their results as those that had been fertilized (II. CONF. 28).

In New South Wales it is believed by some that wheat should never be sown in freshly-manured ground (II. CONF. 33), and in South Australia some are convinced that if the rainfall be light, the more manure is put in the ground the worse will be the crop (III. CONF. 67).

Mr. Farrer (New South Wales) insists on the necessity for securing a variety of wheat that shall be productive in soil of average fertility without the use of manure (II. CONF. 44). Mr. Pearson (Victoria) while agreeing that it was not necessary to manure unless it would pay, pointed out that in Victoria it paid to manure barleys, and to overlook the necessity for manuring wheats would be a mistake (II. CONF. 45).

Mr. Shelton (Queensland) does not believe that the Queensland farmer can afford to manure a wheat-field. In America where the conditions are similar, no one manures directly. They manure indirectly by pasturing, by maize, or by green-crops, giving the manure to the crop preceding the wheat and so "taking the edge off" the manure (II. CONF. 45).

Disinfection of soil.

§ 27. Several special preventive applications have been tried. Thus "limeing" was experimentally tested in Victoria in 1890 and the following season. In both cases it was ineffectual (II. Conf. 7, 21; III. Conf. 46); on the contrary, it caused a rather heavier flag and thus increased the liability to rust. In Queensland, on the other hand, it was rather favourably reported on (II. Conf. 30).

Potash salts appeared to decrease the rustiness when used in the form of chloride (II. Conf. 7; III. Conf. 46). As nitrate it seemed to toughen the straw and to force the growth of the plant, but as there was little rust about, the experiment was inconclusive (II. Conf. 21).

Common salt and sulphate of iron appeared in Victoria to have an antiseptic property and diminished rust. At the same time they diminished the outturn of grain (II. Conf. 7; III. Conf. 46). In another series of experiments the plots treated with salt were decidedly the cleanest (II. Conf. 14). The result is probably due to the salt stunting the growth of the plants, toughening their straw and checking the tendency to flagginess (II. Conf. 21).

In Queensland, too, salt applied broadcast at the rate of 300lb [per acre?] is said to have often given favourable results (II. Conf. 30). But the experience of South Australia is that neither kainit nor salt have any preventive effect (II. Conf. 50), and in Victoria renewed experiment showed that, while salt strengthened the crop, it did not lessen rust (III. Conf. 15).

Sulphate of ammonia and superphosphate of lime, one part to three, recommended as a rust-preventing manure, was found to increase the yield, but did not diminish the rust (III. Conf. 15), and in New Zealand *á propos* of a series of experiments with a so-called "preventive" manure sent to Wellington from Australia, Mr. Bayne, Director of Lincoln College, finds that "no manure has yet been discovered that is a preventive of rust in cereal crops" (Sub-conf. O. 494).

Disinfection of Seed.

§ 28. The treatment by disinfectants of the seed to be sown was at first supposed likely to be useful (I. Conf. 53) and has been fully tested. The substances employed have been sulphate of copper, carbolic acid and hot water.

Sulphate of copper did nothing to prevent rust (II. Conf. 14, 46; III. Conf. 15, 21), on the contrary it was considered in New South Wales to have diminished the germinating power of the wheat (II. Conf. 32).

Carbolic acid was a failure; there was a greater loss from 'Smut' after its use than the observer had ever experienced (II. Conf. 21). This is interesting, because the pickling process, with sulphate of copper at all events, though not efficacious against rust, is good for preventing 'Smut' (II. Conf. 36).

The hot-water treatment, which is said to have been found efficacious in Denmark, was recommended (III. Conf. 68), but found useless (Sub-conf. J. 15).

No process of pickling can be expected to be useful, for though a few spores may be entangled in the "brush" and the application might destroy these, there is no mycelium in the seed. Rust does not often affect the seed at all and has never been known to enter the seed while in the ground and before the appearance of the leaves. It may and does attack the plant at any stage after it has appeared above the surface of the ground; this, so far as is known, is the only way in which it does attack the plant. No treatment of the seed can, therefore, be of the faintest use (Cobb, Contrib. vol. III., p. 183). The actual demonstration of this fact is recorded (IV. Conf. 29).

The subject has received very careful attention in Victoria. Twenty different modes of treatment were adopted and the result was to show "that the treatment of seed for rust is a delusion." The hot-water treatment was not more successful than the others. It appeared rather to hasten germination though the proportion of seeds to germinate was lessened, and the ripening was somewhat retarded (IV. Conf. 25).

The view that any treatment of the seed is valueless was adopted as an undoubted conclusion at the last Conference (V. Conf. 3).

Use of mouldy seed.

§ 29. The use of seed that has by accident become mouldy has been advanced as a possible cause of rust. This question has been settled by experimental sowings in South Australia which show that sound dry wheat-grain does not resist rust, while mildewed wheat does not prove more liable to rust than dry grain (II. Conf. 46).

Use of rust-shrivelled seed.

§ 30. The fact that the sowing of rust-shrivelled wheat is not attended by any inherent bad consequences has been long known. The famous breeder, Mr. Jethro Tull, wrote, in 1751, that "some have thought that a large grain of wheat would produce a larger plant than a small grain, but I have full experience to the contrary. Farmers in general know this and choose the thinnest, smallest-grained wheat for seed, and

therefore prefer that which is blighted and lodged." And Sir Joseph Banks in 1806 noticed that rust-shrivelled wheat may be employed for seed. Doubts have been thrown on this experience, however, and the Australian results and conclusions are consequently of very considerable value.

In Victoria it was found experimentally (Port Fairy) that the healthy seed gave the better outturn, but that there was no clear evidence that the liability to rust was less with healthy than with shrivelled grain (II. Conf. 8). In the following season the Port Fairy farm showed that the yield from rust-shrivelled seed was only 7½ bushels per acre, as compared with 13½ bushels from healthy seed (III. Conf. 47). At another experimental station (Dookie), it was found that the yield per acre from rust-shrivelled seed was about 20 per cent. greater than from healthy seed, and the sample was also of superior quality; but that the plants raised from shrivelled seed were perceptibly more rusty than those raised from plump seed (II. Conf. 13).

The latter experience is more in accordance with what is at all events the general belief. The vast majority of Victorian farmers have found the product of rust-shrivelled seed to be at least equal to that of plump seed in quality and yield. If the rustiness of the resulting crop be taken into consideration, it seems to be much the same in either case. Many indeed state that they have never seen a rusty crop from rusty seed; these are probably observers who have not had the misfortune to experience two consecutive rusty years, for when one rusty year follows another, rust attacks both sorts equally (II. Conf. 21). The second generation of the rust-shrivelled seed when sown yielded good crops, but just like the original stock; when rust was present it was affected precisely as the crops from other sorts were (II. Conf. 20). The general opinion in Victoria is, or was, that rusted is quite as good as plump grain (III Conf. 20).

In South Australia it is considered that there is evidently no disadvantage in using rust-shrivelled seed; indeed, if the evidence leans to any side it is in favour of using rusted seed (II. Conf. 51).

In New South Wales the opinion expressed by 17 farmers in 1890 was in favour of plump seed as rust-resisting, only 5 favoured shrivelled seed, and 14 were indifferent. Some of those who sowed rust-shrivelled seed claimed a heavier outturn from it (II. Conf. 32). Dr. Cobb, however, says shrivelled seed is as good as plump so far as mere germination and outturn are concerned, though he favours plump seed (II. Conf. 35);

and in the following year it is said that the general conclusion in New South Wales was that rust-shrivelled grain is not worse than plump grain.

In Queensland, of 60 farmers who used rust-shrivelled wheat, 55 reported having obtained excellent results, and the others only objected on theoretical grounds (II. Conf. 28).

Mr. McAlpine (Victoria) finds that the germinating power of rust-shrivelled seed is sometimes inferior and sometimes superior to that of plump seed, but, generally speaking, rust-shrivelled germinates just as well as plump. The liability to rust was equally great *in the same variety of wheat* whether the crop was raised from rust-shrivelled or from plump grain. The yield from an equal number of rust-shrivelled grains was, however, superior. These results confirm the general opinion of farmers, which is that rust-shrivelled seed may be safely sown, especially if the land be in good condition and the season favourable for giving the seed a good start. They also confirm the results obtained at the experimental station, Minnesota, U. S. A., where shrivelled seed with careful cleaning and winnowing was found to be safely usable (Sub-conf. L. 22). Even if no harm results from using rusty seed, showing that the disease is in no way of a hereditary nature, necessarily no particular benefit is to be derived from the use of rusty seed since it is not rendered in any way immune against rust, even in the first generation (II. Conf. 21).

Mr. Pearson (Victoria) discussing the subject points out that if it be a question of using plump seed of a crop that has merely "escaped" rust in the preceding year, or of using shrivelled seed of a crop that has been rusty, there is little to choose between them. But if it be a question of using seed whose plumpness is due either, (1) to the plant, though exposed to all the risks of rust infection, resisting these; or (2) to the plant, though infected, still having the constitutional ability to make a fairly plump seed, then it is better to choose such a plump, or fairly plump, seed than to select shrivelled seed. For when the plumpness of the grain is due to constitutional causes in the parent plant, that grain or seed is very much superior to shrivelled grain and ought always to be sown in preference. When, on the other hand, the plumpness is due merely to external conditions of growth, the superiority of such seed over rust-shrivelled seed is not so great, and may at times not be apparent at all (III. Conf. 57).

Mr. Shelton (Queensland) puts the same argument in a somewhat different way. The variety and the time of seeding,

not the quality of the sample of speed, determine the ability of the crop to escape rust-contagion. There is a cogent reason for avoiding seed that bears the marks of the disease; the very fact that the seed has thus suffered from rust is proof that it belongs to a rust-liable variety, and so may be expected to produce a crop strongly susceptible to rust-infection (SUB-CONF. J. 15).

Mr. McAlpine (Victoria) expresses a similar opinion. The rust-shrivelled grain is certainly *not more liable, per se,* to propagate rust in a rusty season. But in selecting seed *for the production of rust-resisting varieties,* one would naturally choose seed with a clean record and as far as possible without the taint of the disease (SUB-CONF. L. 22).

The final report of the Committee at the most recent of the inter-colonial conferences forcibly endorses this opinion, which it puts forward as one of two conclusions at which the conference has arrived, *viz.*: — "that the notion that rust-shrivelled seed can be sown with as good results as plump seed is erroneous" (V. CONF. 3).

A rust-shrivelled grain is hard, dry, generally uninjured in threshing, and contains more gluten and less starch than ordinary grain; in testing the germinating power of the two, Mr. McAlpine found that 87 per cent of shrivelled grain germinated as against only 67 per cent. of plump (SUB-CONF. L. 22). [No doubt the excess is partly to be explained by the diminished liability to physical injury in the case of shrivelled grain. At the same time the presence of starch *in such excess as to cause the grain to be plump* may be a condition as unnatural as the presence, in excess, of fat in the liver of a Strassburg goose; anything therefore, like an attack of rust, that tends to reduce the amount of starch would tend, *pari passu,* to render the wheat-grain less unnatural and, consequently, physiologically more vigorous. This, however, to be an unmixed benefit, would imply that the effects of rust were limited to the prevention of excessive formation of starch; as we know, the effects of a severe attack of rust often lead to the inability of the plant to form a grain at all.]

In Mr. McAlpine's experiment, however, the plump grain in question was the product of the rust-shrivelled seed and the latter was therefore a year older. Commenting on this experiment Professor Sorauer concludes that the germinating power of rust-shrivelled grain is improved when the seed is a year old, an aspect of the question that had not occurred to Mr. McAlpine who, however, is now inclined to think that

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the germinating power of all seed is increased by keeping it till it is one year old. At any rate many farmers think so; some even suppose that keeping seed for a year tends to lessen the severity of the effects of rust. (SUB-CONF. L. 22). The use of two years' old seed becomes, therefore, one of Mr. McAlpine's recommendations (III. CONF. 21).

Use of special size of seed.

§ 31. The use of a special size of seed of any variety, though this selection has no bearing on the question of immunity from rust, has been incidentally dealt with.

In all cases small seeds should be avoided as they yield a decidedly lighter crop. In some cases likewise the largest should be excluded as these also yield a crop lighter than average though less light than that yielded by the smallest seeds.

From the largest heads the yield is much the most prolific. The yield indeed is far greater from the smallest seeds of large heads than from the largest seeds of small heads. There seems, however, to be no special benefit obtained by selecting seed from any special part (middle or upper or lower third) of the head (III. CONF. 57).

Supposed Heredity of Rust.

§ 32. The experience obtained during the enquiry into the question of rust-shrivelled grain has, in the opinion of Australian observers, quite satisfactorily disposed of the belief that Rust is a hereditary disease. What is hereditary is a liability to affection in certain varieties of wheat; unfortunately this susceptibility is not confined to such varieties; for breeds of wheat that prove fairly rust-resisting in certain countries or districts fail to escape when sown elsewhere, and wheats that escape rust in one district during a certain season may suffer most in the same district during another (I. CONF. 53). A careful perusal of the latest expression of European opinion (APPENDIX A.) will, however, show that the point is by no means definitely settled; on the contrary, it is probable that the older view, expressed by W. G. Smith and others (*Queensland, Dept. of Agricult.; Report on Insect and Fungus Pests*, n. 1, 1889, p. 210; *Gardeners Chronicle*, 1885, ii, 21) is correct, and that rust is hereditary. The explanation of the fact that is offered by Mr. Smith is, however, certainly insufficient.

Disinfection of standing crop.

§ 33. The treatment of the growing crop for the palliation or prevention of rust, though at first it seemed a hopeful line of experiment (I. CONF. 63), has proved useless.

The effect of spraying with common salt was *nil* as regards diminution of rust; it, however, materially decreased the

outturn of grain (II. Conf. 7) when the experiment was tried at the Port Fairy Farm, 1889-90. Spraying with sulphate of iron at this farm both lessened the quantity of rust and increased the outturn of grain. It was computed that with a suitable spraying instrument the substance might be applied at a cost of one penny per acre. The result is stated to have been that for 4*s.* 6*d.* spent in spraying with sulphate of iron, six additional bushes of wheat were obtained.

At the Childer's Farm similar experiments seemed to show that sulphate of iron protected the wheat subjected to the spray, for about a fortnight. It was even claimed that the spraying *cures* rust. The period of risk is not perhaps more than a month to six weeks; three sprayings during this period should, therefore, effectually save the crop. The cost should be, at the outside, 1*s.* 6*d.* per acre; and the application need only be made in rusty years (II. Conf. 13). In Victoria, therefore, spraying with a suitable solution was strongly recommended (II. Conf. 21).

Dr. Cobb (New South Wales) favoured spraying on theoretical grounds on account of its having proved effective in peach-rust and other blights (II. Conf. 31), and in 1891 he believed that he had settled beyond doubt his ability to recommend a solution to be used with the strawsonizer which will kill the spores of rust (II. Conf. 35). The bloom of wheat prevents any but the finest spray affecting it, hence the rust may be wetted more readily than the wheat. "Saccharate of copper," or bluestone and treacle, as used in France, was considered by Cobb likely to prove useful, the treacle causing the fungicide to remain on the plant (II. Conf. 36).

In the discussion on this subject at the Second Conference Mr. Pearson (Victoria) considered the strawsonizer unlikely to give spray fine enough, though he deemed spray likely to be of use. Mr. Shelton (Queensland), while not disputing the theoretical value of spray, thought that a new race of farmers would have to be bred before the remedy could be applied. And he asked for caution in recommending spray, first because of the many sprays recommended that prove in time to be valueless, and again because, supposing the sprays to be effective they could not be got upon the plants (II. Conf. 38).

It was pointed out that, so far as the experiments went, they showed that spray applied before rust begins does no good; the answer was that "Saccharate of copper solution" meets the difficulty, because it stays on the plant (II. Conf. 38). Mr. Pearson insisted that spraying should only be

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regarded as an expedient of a temporary nature, pending the production of rust-resisting or rust-avoiding varieties, and to this Mr. McAlpine (Victoria) agreed, but urged their use till such time as a rust-free wheat is evolved (II. Conf. 44, 45).

In the next year's experiments it was found that, while spraying with sulphate of copper temporarily cleaned the straw, it got rusty again later on (III. Conf. 15).

At Port Fairy the experiments with sulphate of iron were repeated in 1891. The spraying did appear to kill the rust in the plants to which it was applied, but the rust re-appeared and the beneficial effects were masked or lost. As good results as any were obtained by using 2 oz. of sulphate of iron to the gallon and applying 30 gallons of this solution per acre. There seemed no advantage in exceeding 30 gallons, whatever the strength, even with a dense crop 5½ feet high.

The experiments were deemed a partial success; but for the best results a steam-spray was considered essential (III. Conf. 46). Indeed in Victoria generally spraying with sulphate of iron was supposed to be a decided success (III. Conf. 21).

At the Adelaide Conference of 1892, however, Dr. Cobb thought it doubtful if spraying was worth going on with. If employed it should be as short, quick sprayings, so that the water should remain divided and not run into drops (III. Conf. 29).

In Queensland the experience of 1891 was that spraying "counts for nothing" (II. Conf. 61), and the South Australian experience was just as disappointing (II. Conf. 24, 66). At the later conferences the matter was not even discussed.

Time of sowing.

§ 34. The time of sowing appears to be of the highest consequence, in Australia, in connection with the rust-problem. The comparative absence of rust from self-sown wheat, which is always early, is used as an argument in favour of early sowing (II. Conf. 21), but as it is at least doubtful if such wheat be less rusted (Sub-conf. J. 15; III. Conf. 20), the argument fails.

Early sowing has been the remedy most in favour from the outset (I. Conf. 63). It is found that early sowing greatly diminishes the degree of rustiness: it diminishes the outturn, however, at the same time, for the effect of sowing a fortnight too early has decreased the outturn as much as 33 per cent., though at the same time it ensured freedom from rust. Late sowing increases the risk of rust very greatly; wheat sown a fortnight too late had a much diminished outturn, and was at

the same time badly rusted. Sowing too soon is, therefore, a safer mistake than sowing too late (II. Conf. 10). Early sowing is generally acknowledged to be best, as by that means the crop has a greater chance of avoiding the rust or of coping with it if attacked. This is repeated again and again in the Australian literature of rust (II. Conf. 25, 28, 30, 32, 33, 35, 44, 45, 50; III. Conf. 14, 20, 22; Sub-conf. J. 14; O. 495).

An interesting instance, as bearing out the same rule, is quoted from one of the Victorian experimental farms (Dookie) where a recently imported English varietv produced a thick crop late of maturing and was very rusty (II. Conf. 14). The same was the experience with 12 freely tillering Swedish wheats, specially imported because in Sweden they are rust-resistant (IV. Conf. 21). The beneficial effects of early sowing were very marked at another of these farms (Port Fairy) in 1891, all the more so because rust in that year came on very early. The difference of outturn between wheat sown on May 27 and June 4 was 8 bushels per acre, on May 27 and July 15 was 18 bushels per acre in favour of the earlier sown (III. Conf. 48).

The middle of April to the middle of May is given as the time for sowing in Queensland, the precise date depending on the weather (II. Conf. 28). In New South Wales May is late for sowing and any subsequent month is too late to sow to escape rust (II. Conf. 32). In South Australia wheat cannot be profitably sown after May, and land sown with wheat in June or July would be more profitably cultivated if laid down in some other crop (II. Conf. 50).

If, however, early sowing be a good general rule, there are exceptions to it (II. Conf. 50; Cobb, Contrib., vol. III., p. 183). One danger is that a late frost may pinch the wheat while in bloom (II. Conf. 98). Another is that muggy weather may set in about the time the wheat of the early sown crop is in flower and thus favour the development of rust which the later sown might escape or be little affected by. Thus in Victoria in 1889 whereas early sown crops only suffered to the extent of 4 bushels per acre while late crops lost 8 bushels, in 1887 the early sown suffered most (II Conf. 16). It would appear indeed that in nearly all the years given as "rusty years" for Australia the early sown wheat suffered badly (IV. Conf. 20).

On the whole, however, early sowing is the safest rule; but it is mainly of value when associated with the selection of early maturing varieties (II. Conf. 16, 33).

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Mr. Farrer, the great authority on wheat-breeding, insists strongly on the advantages of early sowing for all wheats, whether they be late or early of maturing. The influence goes beyond the effect it has in making them ripen sooner. If two wheats, equally liable to rust, be sown, the one an early and the other a late variety, and the early variety is sown late, while the late variety is sown early, Mr. Farrer's experience leads him to think that although the late-sown early variety may ripen before the early-sown late variety, it will be more liable to rust than the other (II. Conf. 44, *note*).

Mode of sowing.

§ 35. As might be expected it makes no difference to the liability to rust either way, whether the wheat be drilled or sown broadcast (II. Conf. 19, 51).

Thin-sowing as opposed to thick is favoured in Australia on theoretical and on practical grounds. Newly imported thick-growing sorts are apt to be much rusted (II. Conf. 14), as are rank and flaggy crops on rich or virgin soil (II. Conf. 19). Any lodged portion of the crop is similarly affected (II. Conf. 22). Actual thick-sowing is found by the majority of Australian farmers to cause greater liability to rust. This is the experience in Victoria (II. Conf. 19); in New South Wales (II. Conf. 32; III. Conf. 10); in South Australia (II. Conf. 49, 51). In Queensland opinions differ greatly (II. Conf. 28). Nevertheless there is a preponderance of opinion in favour of thin-sowing everywhere throughout the Colonies and it is recommended by the conferences (II. Conf. 28, 30, 32, 51; III. Conf. 14, 20; Sub-conf. J. 14). In Queensland a thicker seeding is recommended in forest land as the soil there is less rich.

The experience in Canada and in England is the reverse of the Australian; in these countries thick-growing crops are less rusted than thin (II. Conf. 7, 19). There the greater coolness due to ventilation may be counterbalanced by the greater warmth due to better penetration of the sun's rays (II. Conf. 7). In Australia the thin-growing crops are possibly cooler, from the greater evaporation due to better ventilation, than thick-growing crops are. Besides, thick-sown wheat comes up heavy and rank, and the flag exposes a larger surface to infection, at the same time it renders the access of sunshine to the flag impossible, and thus diminishes the resisting vigour of the leaves (II Conf. 32). For this reason, besides merely sowing the crop thinly, it is advisable to select varieties of spare habit, upright in growth and lightly flagged.

Changes of seed.

§ 36. Besides sowing on a dry seed-bed Mr. McAlpine in his summary of recommendations advises thin and early

sowing of two years' old seed, changed frequently from a colder climate (III. Conf. 21), this being considered, as a rule, most satisfactory. But local conditions are said to modify the last statement as a general conclusion (II. Conf. 14, 33), and Mr. Lowrie is of opinion that when the change of seed is from a colder to a hotter climate, the susceptibility to rust is increased. It has at all events always been so in the case of wheat introduced to Australia from England, America and New Zealand (II. Conf. 50). The same has been the experience with Swedish wheats reputed to be rust-resistant, in certain instances these proved complete failures; in the worst cases, however, "the samples were rather late in being sent for sowing as early as the district requires" (IV. Conf. 27).

Nor has the opposite experience, sowing seed from a hotter climate, been altogether satisfactory. In Queensland reference is made by the Honourable Mr. Macansh to a wheat originally received from India that had been grown on Canning Downs for 8 years up to 1892, and had never been rusted; also to another very early Indian kind grown for 3 years up to 1892 that had never shown any rust even on the flag (Sub-conf. J. 22). The conditions in Queensland are perhaps more like those in India; in Victoria, however, the experience with Indian wheats was very poor indeed; the particular kind tried was a race named *Pissi* received from the Central Provinces (Sub-conf. L. 18). Now *Mundia pisi* chances to be one of the kinds reported by the Chief Commissioner to have some power of resistance against rust (*Resol. Rev. Adm., C. P.*, 1894-95, p. 2); as a set-off it may be noted that cross-bred wheats from Australia, supposed to be rust-resistant, fell victims to rust in the Central Provinces in a year when rust was not prevalent; it must be noted, however, that the crop had to be subjected to conditions as regards irrigation that are found to be unfavourable in Australia (*Rep.* by *Comm. of Settlements and Agric., C. P., on cross-bred wheat*, 1897).

§ 37. To save a crop attacked by rust it has been recommended that it should be cut in the 'dough'-stage; that is, before the crop is ripe, and while the grain is still soft, though no longer fluid in the centre as it is in the still earlier 'milk'-stage. Time of reaping.

In Victoria official experiments seemed to show that grain from wheat cut in the dough-stage was superior to grain from wheat cut when ripe; the yield per acre in 1890 was, however, slightly less (II Conf. 10). In 1891, the wheat cut in he dough-stage yielded 38·7 bushels per acre, that which was

cut ripe only 33·3 bushels; this, however, it is admitted, may partly be accounted for by accidental variations (III. Conf. 48). The general farming opinion, in 1891, seemed slightly in favour of reaping in the dough-stage in Victoria (III. Conf. 18).

In New South Wales the matter is considered debateable. In 1890 (II. Conf. 32), the practice was supposed to be generally favoured, because it not only saves waste of grain from shedding out, but also arrests the ravages of rust if the crop be only slightly diseased. But, to take full advantage of the practice, early maturing varieties of wheat must be secured.

Mr. Farrer (New South Wales), dealing with this matter at the Second Conference, said that reaping in the dough-stage possesses so many advantages both for millers and for growers that its recommendation is not astonishing. But it is not desirable *at all times*, and is particularly undesirable in the case of grain to be used as seed. Mr. Farrer's statements are given on the authority of Professor Blount, who finds that, when grain is picked in the dough-stage, the germinating power is greater and the growth more vigorous but the grain after such an operation is *not so good* for seed. All seed-grain should be perfectly ripe when picked. No explanation has been given why seed picked in the dough stage should grow more vigorously, but for a single season it certainly does so; after that, deterioration is fatal and rapid. For milling, on the other hand, it is better to cut in the dough-stage, on the principle that grass is cut before going into seed as it is then more nutritious.

Mr. Farrer is strongly of opinion that much of the deterioration—the "running out"—that takes place in the majority, if not all, the "standard" varieties of wheat can be traced to the practice of harvesting seed while still immature. And he urges that grain to be used as seed should not be reaped in the dough-stage (II. Conf. 41). This recommendation was adopted by the Second Conference (II. Conf. 52).

In 1891, however, it appeared that farming opinion was divided as to the benefit to be got from reaping even the rusted crop in the dough stage (III. Conf. 15); Mr. Farrer, moreover, insisted that it had now been satisfactorily proved that it was more profitable to allow wheat to become ripe before harvesting it (III. Conf. 36).

The experience of thirty-three Queensland farmers is given in connection with this point. Eleven got good grain, twelve got pinched and shrivelled grain, ten got worthless grain

(II. Conf. 28). Mr. Shelton (Queensland) explained that as regards maize he had shown by experiment that in reaping at all stages of ripeness,—milk-stage, dough-stage, and dead-ripe—there is a progressive increase in yield the later the stage; each day later shows a difference in favour of the result, the total difference from earliest to latest being one of 8 bushels yield per acre. But what seemed true of maize was not, of necessity, true of wheat (II. Conf. 45); if reaping in the dough-stage be satisfactory, in wheat it is doubly advantageous, since wheat cut then is understood to give better flour (II. Conf. 38). In any case reaping in the dough-stage is to be recommended in preference to indiscriminate cutting as hay in the milk-stage, which is a very common practice in Queensland if rust appears on the plant during that period (II. Conf. 30), and which is sometimes adopted in Victoria (II. Conf. 22) also.

Mr. Inglis (South Australia) instanced a case where some wheat cut very early had a nice small grain, whereas what was left in the paddock all went to powder (II. Conf. 45). This corroborates the advantage claimed for reaping before ripeness; on the other hand, Mr. Kelly (South Australia) mentioned a case where a field of 400 acres tried by the reaper did not produce any grain. Sheep were, therefore, turned on till, in July or August, the plants were allowed to grow; the ultimate result was that the field yielded 15 bushels an acre (II. Conf. 35).

Professor Lowrie has given very interesting and useful evidence on this point. In South Australia the stripper is largely used, for this reason the wheat must be permitted to become dead ripe. If cut in the dough-stage the grain shrivels less from rust, but the advantage gained was less than might have been expected. In 1890, in five cases where equal blocks of wheat were laid off in pairs and one block of each pair was cut early and threshed, the other of each pair allowed to become dead ripe and then stripped, it was found that, in four cases out of the five, more wheat was got from the stripped than from the threshed blocks though the sample was about 2lb per bushel lighter (II. Conf. 50).

Repeating his investigations in 1891, Mr. Lowrie found that cutting with the binder in the dough stage and threshing afterwards, the yield was 12 bushels 10lb per acre; cutting nine days later the yield was 11 bushels 10lb. The same wheat stripped gave 10 bushels 28lb; the result was, therefore, slightly in favour of the binder with subsequent threshing, and slightly

FUNGI.	Resumé of Recommendations.

in favour of cutting in the dough-stage. The previous year the result was slightly in favour of the stripper.

Stripping is in favour in South Australia because the yields are so light and threshing is so costly; if the yield be under 15 bushels an acre the stripper is the more economical machine; with higher yields it would be advantageous to use a binder and thresher, and thus get straw as well as grain (III. Conf. 66).

In 1894, the Fourth Conference only recommended the harvesting of rust-infected crops in the early or dough stage (IV. Conf. 48), and the subject is not dealt with in the Committee Report of the Fifth Conference.

Resumé.

§ 38. Reviewing briefly the proposals for the prevention of Rust, it may be said that drainage *per se* is not a palliative, nor is irrigation *per se* an excitant; it seems to be on the whole advisable to sow in a dry seed-bed. Rotation of crops appears to be advisable for practical reasons as well as on theoretical grounds; a thin crop is advisable in Australia, as it probably also is in India, although the experience of cold countries is the reverse to some extent: a comparatively poor soil also is preferable to a rich or heavily manured soil; this, for the very reasons that prevail in Australia, is probably true of India also. Treatment of the soil with special preparations is a mere throwing away of time and money; the disinfection of the seed before sowing and the disinfection of the growing crop are equally valueless. The use of rust-shrivelled seed is not *per se* a cause of rust, but it is to be avoided because the fact that it is rust-shrivelled indicates that it belongs to a rust-liable stock. The one great palliative is early sowing.

The reaping of wheat before the seed is fully ripe yields a grain that finds favour in certain markets, but is not a course to be adopted at all where the grain is to be used for seed and is not an act to be recommended except in the case of a rusted crop.

The most rational treatment is put briefly and clearly by Mr. Bayne, Director of Lincoln College, New Zealand (Sub-conf. O. 494):—Clean culture, judicious rotations, fallowing of lands, sowing early, and selecting accredited rust-resisting varieties of seed. The last recommendation is that which is most hopeful, since it attempts to eliminate the factor of inherent susceptibility. The history of the efforts of Australian wheat growers in this direction forms the subject of the concluding chapter.

Chapter IV.—RUST-AVOIDANCE.

The best remedy for rust.

§ 39. At the Second Conferenee Mr. Farrer (New South Wales) expressed the opinion that the best method of combatting rust is to secure or create resistant varieties with the characters demanded by the special requirements of Australia, and possessing, together with high milling qualities, such powers of resistance to the pest as to give them value on that account (II. Conf. 39).

Wheats reputed Rust-proof.

§ 40. That certain wheats, under what appear to be identical local conditions, escape rust in particular seasons and in particular localities is well-known, and the selection of these wheats is strongly recommended (I. Conf. 43; II. Conf. 22, 39; Sub-conf. J. 22; O. 494).

It is said that practically rust-proof wheats exist in the Bombay Presidency, and in Japan also it is said that practically no rust exists. A set of wheats have been evolved in Japan that do not exceed 20—24 inches in height, with straw so stiff and strong as to stand the severest storms. These stiff strong-stemmed sorts are just the kinds likely to resist rust. It is, Mr. Shelton (Queensland) thinks, not improbable that rusty regions may have become practically rustless by the selection of rust-free kinds. For Japan, at least, with its practice of irrigation and its free use of nitrogenous manures, with its mild climate and its excessive humidity, the climate and conditions are all those that are most favourable otherwise to the development of rust (III. Conf. 62).

However, the escape of a wheat from rust in one season is no proof that it is rust-resisting (II. Conf. 36, 50). Many wheats also that seem rust-resistant in one locality fall victims to it in another; *e.g.*, a wheat that is rust-proof in a maritime district may be badly rusted inland, and *vice versâ* (II. Conf. 9; III. Conf. 36), and it is admitted that such a thing as a rust-proof wheat does not exist (II Conf. 30; III. Conf. 22, 28; Sub-conf. L. 15).

Proof against rust *versus* poor outturn.

§ 41. The question has arisen whether it is advisable to sow a wheat that has the reputation of being able to resist or escape rust, or to presume that the season is not to be a rusty one and to sow a wheat that, though notoriously subject to rust, possesses other qualities that render it the more desirable of the two.

Thus, freedom from rust and prolific yielding are said rarely to go together, and if the two qualities are found to be incompatible, one Victoria delegate urges that the latter

quality must be preferred. It is better to run the risk of an occasional bad year than to always have a meagre outturn. If they are not incompatible, and the evidence advanced does not go to prove incompatibility, it is open to select from, and improve upon, tried rust-resisting varieties, or to select from known prolific yielders rust-resisting strains (II. Conf. 9).

Mr. Shelton (Queensland), however, strongly deprecated the cultivation of risky sorts that fetched a penny or so per bushel more when there were many varieties in existence better able to withstand rust (II. Conf. 45). A South Australian delegate, too, was of opinion that farmers should always grow a proportion of these rust-resistant wheats to avoid a total collapse of the wheat crop in any year (II. Conf. 50). In any case it is admitted that sorts which are poor yielders in one district are prolific in another (II. Conf. 9).

Classification of wheats with reference to rust.

§ 42. From the point of view of their resistance to rust Dr. Cobb gives the following classification of wheats:—

(1) *Rust-proof Wheat.*—A wheat that will not permit the mycelium of any rust to enter and feed on its tissues. No such wheat is known to exist, but the term is convenient for purposes of comparison.

(2) *Rust-resistant Wheat.*—A wheat that under conditions favourable to its growth resists at all seasons of the year the entrance of the rust-mycelium into its tissues, or if the mycelium of rust has found admission, resists its subsequent growth and development. A number of such wheats are known, and from this class selection of existing or creation of new varieties should take place.

(3) *Rust-liable Wheat.*—A wheat the opposite of rust-resistant. Most wheats are of this class; and should be avoided or, if retained, hardened by cross-breeding with rust-resistant kinds.

(4) *Rust-escaping Wheat.*—A wheat that, if sown at the proper time, matures its grain so quickly as to be ready for harvest before the rust of an ordinary season can prevent a paying crop (III. Conf. 28).

Earliness of crop.

§ 43. One of the leading characters of rust-resistant wheats is that of ripening early, and this is consequently given as a character to be attended to (II. Conf. 25, 50; III. Conf. 45). However, the earliest wheats are apt to "shell," and this is a feature that must be eliminated by selection from any such

wheat, adopted as a rust-resisting or rust-escaping sort (III. Conf. 38); the chaff should hold the grain firmly and well (III. Conf. 36). According to Mr. Farrer, too, early maturity does not of itself enable a wheat to resist contagion; all it does is to ensure that it is beyond the susceptible stage before contagion is abroad (II. Conf. 43). Many of the varieties reputed to be rust-resisting are nothing of the kind; they are only early-maturing kinds that therefore often escape. If such kinds chance to be late, or if rusty weather comes on early, they are invariably affected (II. Conf. 43). It is even found that a rust-resisting wheat may (just like a rust-escaping one) succumb to rust if subjected to unfavourable conditions; for example, such kinds, though normally free from rust, may be just as rusty as their neighbours if "lodged" and smothered (III. Conf. 57). Therefore, though earliness is always a property to be aimed at and is desirable in all kinds of wheat, it is not in itself sufficient to ensure safety. Besides, farmers are not always able to sow early (I. Conf. 43; II. Conf. 43) and an early wheat, if sown late, is often just as liable as another kind.

Risk from parching winds and from frost.

§ 44. One advantage of early sowing is that it often leads in northern districts to the escape of the wheat from the hot dry winds that sometimes pinch the grain as much as rust does. On the other hand, early sowing often exposes the wheat in cold and late districts to spring frosts at the time the plants are in bloom (II. Conf. 43), and it is even said that for Victoria one of the essential characters of a good variety of wheat must be that it is a frost-resisting one.

Hardness of grain; Bad milling qualities.

§45. Red wheats and wheats with hard, flinty or wiry straw and hard grain suffer least (II. Conf. 32, 36, 50), and in spite of the fact that they are not so desirable for milling purposes, they should be grown and improved upon. Indeed, Mr. Farrer insists that hard grain, which is in correlation with the hard flinty straw, is far from undesirable. Such wheat can be effectively dealt with by roller mills; it is rich in gluten; the bran is often very thin, and it is much less liable to weevil. For the reasons stated, indeed, hardness might be considered essential (II. Conf. 43).

Mr. Shelton (Queensland), in support of Mr. Farrer's contention, points out that the wheats sent from the north-west of America to feed Europe are small, hard, red wheats that a Queensland farmer would despise. Indeed, when good vigorous rust-resisting varieties of the kind are grown in Queensland, the millers cut these down 2*d.* to 3*d.* a bushel as

FUNGI.	Characters accompanying.

compared with white wheats. Yet these hard, red wheats yield the very best flour, superior in nutritive qualities to anything yielded by white wheats. All that is required is suitable machinery to mill and unprejudiced farmers to grow wheats of the kind (II. Conf. 45).

The South Australian delegates, however, appeared to appreciate more keenly the disadvantages of bad milling properties (II. Conf. 48, 50). It is admitted that in 1890 of 100 sorts experimentally grown, only one variety was quite free from rust—an African wheat with large flinty grain and solid straw; this, however, was no sufficient reason for supposing it absolutely rust-resisting. These bad milling kinds should be avoided if better are available, and Mr. Farrer includes the possession of high milling qualities as essential in any variety secured or created (II. Conf. 39). Indeed, as Mr. Farrer admits, rust-resisting wheats have come to be looked on with suspicion in Australia, because of their bad milling properties. The association is, he thinks, altogether accidental; almost all the varieties of high rust-resisting power are of hot-country origin, and in the countries where these resisting varieties have been evolved, milling qualities have not been an object of search (II. Conf. 43). It is, however, insisted that rust-resistance is not confined to hard wheats (III. Conf. 58; IV. Conf. 11). Indeed when wheats are classified in the ordinary commercial fashion into hard and soft, red and white, so that one gets four main groups;—

(1) Soft pale-straw coloured,
(2) hard yellow,
(3) soft pale-red, and
(4) hard dark-red wheats,

with, of course, intermediates, it becomes apparent that there are rust-resisting varieties in each of the classes and, of the Victorian kinds, 3 out of 4 to which top-prices were assigned, were rust-resisting varieties (III. Conf. 58, 59). One delegate even contends that wheats which are soft in one place are hard in another (IV. Conf. 11).

Spareness of habit.

§ 46. It is recommended that wheats selected should be those that are not too luxuriant of growth and that have little flag (II. Conf. 32); varieties of vigorous growth are not suited to Australia (II. Conf. 43). Besides the greater risk of rust alluded to in a previous chapter, this habit of vigorous growth and "free tillering" is associated, in Australia at all events, with the habit of not properly filling their ears. The habit seems to be natural to certain of these varieties.

The explanation perhaps is that the strength of the plant is largely used up in the formation of extra straw and leaves, and they have not sufficient vital power left for the formation of good grain. The Australian experience is that what are termed "improved English" varieties are most at fault in this respect. They have been selected for a moist soil, well furnished with plant-food in the shape, directly or indirectly, of manure, which thus affords food enough for many stems and their grain. In Australia, where the soil is poorer from constant cropping and where, even if manured, it is, from the dryness, not in a condition to give up the food even if manuring were otherwise economical or practicable, such a variety is to be avoided. This doubtless explains how the varieties most productive in England are the least satisfactory in Australia. Having been improved in the matter of foliage so as to increase the leaf-surface exposed to sunshine and favourable to evaporation they are left with relatively insufficient root-force for food-collection in the poorer and drier Australian conditions (IV. Conf. 17, 18). To judge by the account given of their culture (IV. Conf. 27), this is the case with "improved Swedish" varieties also, and to judge by the detailed table accompanying the *Report* on their cultivation by the Commissioner of Settlements and Agriculture, Central Provinces, the same is to some extent true of "improved Australian" varieties in India.

An exception to the objection against vigorous growth must be made, Mr. Farrer says, in favour of all the strains of "Hard" (*Triticum durum*), and also of some of the strains of "Poulard" (*Triticum turgidum*) wheat. The "Durums" in particular are very resistant and have very wiry straw; the "Poulards" have the same characteristics but less markedly: both mill very badly.

Except "Durums" and "Poulards" and one or two varieties with Durum or Poulard blood, all rust-resistant wheats are of moderate or dwarf habit. This habit, Mr. Farrer thinks, may have been naturally acquired in hot countries by the weeding out of vigorous young plants from exposure to rust. The more scanty the foliage, the more silicon there is in the epidermis and the more rust-resistant is the variety. Besides, dwarf wheats are often more productive (II. Conf. 43).

Absence of beard.

§ 47. Mr. McAlpine found bald wheats largely in the majority as regards rust-resisting power (Sub-conf. L. 15).

FUNGI.	Rust-resisting Qualities.

These wheats are advantageous to grow in any case on account of the greater ease with which they may be thrashed.

Size of leaf.

§ 48. Wheats selected should have leaves of stiff, erect habit so as to prevent spores from lodging on the surface (III. Conf. 33, 35). Dr. Cobb further would have the leaves narrow for the same reason and, indeed, would like to see the flag bred off the wheat altogether, letting it rely for nutrition on the sheath alone (III. Conf. 33). To Mr. Farrer this suggestion does not appeal; he fears too great narrowness of leaf must be incompatible with high productiveness, and therefore would not like to see the flag eliminated (III. Conf. 35).

Toughness of cuticle.

§ 49. But the nature of the flag as to uprightness or narrowness is of little moment as these characters only tend to discourage the settlement of spores. The chief character to seek for is a tough cuticle such as accompanies a flinty straw (III. Conf. 33, 35; Sub-conf. L. 23). The question of trying to breed a wheat with stomata too small to admit the entrance of rust has been raised (II. Conf. 36; III. Conf. 32), but in Dr. Cobb's opinion the truly rust-resisting wheat would be one that, though it lets rust in does not let it come out again, as is the case with the red-skinned hard-stemmed varieties (II. Conf. 36). This does not postulate for these varieties a constitutional ability to resist rust, it merely implies that the cuticle, supposing the fungus has got inside the leaf, prevents it from bursting through and forming *sori* (III. Conf. 35).

Glabrous wheats appear to be most affected by rust, and Dr. Cobb therefore suggests the cultivation of hairy varieties; the hairs probably help to prevent the contact of spores with the epidermis of the plant (II. Conf. 32; III. Conf. 36).

Presence of waxy bloom.

§ 50. Glaucous wheats, or wheats with the leaves covered by a thick waxy bloom, should be selected (III. Conf. 33, 35). The comparative freedom from rust enjoyed by such wheats was first noticed by Dr. Bancroft in 1888 (III. Conf. 57). The waxy bloom assists in two ways; it reduces the size of the stomata, or breathing-pores of the leaf, thus rendering the entrance of rust more difficult even if spores settle on the leaves; it, moreover, renders it difficult for moisture and therefore for spores to rest on the surface of the leaves at all (II. Conf. 35). Mr. McAlpine, however, while agreeing in the abstract with this view, points out that if the bloom does not appear till after the entrance of the spores, it can do no good. He finds that some glaucous wheats are anything but free from rust, while some rust-free wheats are only moderately glaucous (Sub-conf. L. 23). A year later, however, Mr.

McAlpine came to somewhat different conclusions. Generally speaking those plants which were very glaucous were not so much attacked by rust. On the other hand, those that were absolutely free were only moderately glaucous. The general opinion of farmers, who are often right in these matters, is that glaucousness is a sign of weakness in a plant. It is, however, a question how far the farmer mistakes for glaucousness a pallor due to want of moisture. Mr. Shelton, no doubt correctly, expresses his belief that the blue tinge taken by the farmer for glaucousness often has nothing to do with that character (IV. Conf. 29).

The only difference of opinion between Dr. Cobb and Mr. Farrer would appear to be that, while both consider earliness the first essential, Mr. Farrer would look on glaucousness as the leading physical character to select, Dr. Cobb would primarily select a toughened cuticle.

Constitutional resisting power.

§ 51. Besides the characters so far described, there should be an attempt to select and increase the indefinite quality of "constitutional resisting power." This can be done by the perpetuation of certain old varieties and by the breeding of new ones (II. Conf. 44 ; III. Conf. 36). These rust-resisting varieties are more likely to be got from young than from old varieties. Such varieties may be obtained by picking out of rusty crops plants that are entirely clean.

Selection of seed.

§ 52. Mere selection of seed from clean or slightly affected plants could at the outside only give temporary results which would continue only so long as equal care is taken in selecting, and could at the outside only produce resistant strains of known varieties. But the resisting quality must soon disappear under continued cultivation. A quality given to a variety by this kind of selection can only be fixed by cross-breeding, so as to make it a normal characteristic of a fixed variety (III. Conf. 44). In fixing such types it would probably be necessary, as in the case of cattle, to intercross three breeds (II. Conf. 47). It is suggested that wheats are weakened by continuous cultivation (II. Conf. 48).

It is of course always possible that a variety so elaborated may only be resistant to one kind of rust. Wheats that seem naturally rust-proof against one often succumb to another, and wheats that have obtained a good reputation and have suddenly been found to fail, may really have had the power of resisting one rust, but may have on the occasion of their failure been attacked by a different one. It is thus needful to have farmers distinguish, if possible, between one rust and another,

and when they report the fact that a variety has failed, to be able to say which rust did the harm (III. Conf. 44).

Changes in character of varieties of wheat are continually going on. This is well instanced in Australia by the fact that formerly, when hand-reaping prevailed, the object was to grow wheats that ripened gradually—now that reapers and strippers are used the object is to have only evenly ripening kinds (II. Conf. 48).

Practical considerations in selecting seed:

§ 53. In selecting wheats that are rust-resisting there may be other faults. They may have poor heads giving a poor outturn, or they may have bearded heads causing difficulty to thresh and clean; they may have thin and loose chaff and thus not hold the grain, a grave fault if the grain has to be harvested in a state of dead ripeness; this point has been already alluded to. Then the cuticle may be hard but the straw be brittle and weak, a grave fault if the crop is liable to be exposed to storms or heavy rain. The habit of suckering from the root and of having tillering shoots spreading horizontally is also to be avoided; the former character leads to uneven ripening of the crop; the latter renders it liable to the same objection as brittleness with reference to storms, and in any case gives a crop that does not stand up well before the reaper or stripper (II. Conf. 44; III. Conf. 35).

Nature of Straw.

Habit.

Another point to be ascertained in selecting seed is that the spareness of habit, a character otherwise indicative of a rust-resistant variety, be not due to constitutional weakness, and it must, moreover, be noted whether the escape from rust has not been due to mere unhealthiness on the part of the plant and to its consequent inability to harbour and nourish the parasite. Such plants are not uncommon; they are betrayed by their pinched ears (III. Conf. 35).

Nature of Bran.

One of the characters that militate against any variety of wheat is the possession of a thick skin and the production of much bran (II. Conf. 48). It should therefore, in selecting varieties, be an object to secure a thin-brannied grain, long rather than short or round, small or medium rather than large, with a shallow crease and a rounded but not too prominent germ; a deep furrow is very objectionable as it increases the amount of bran and harbours dirt, a prominent germ gets injured in thrashing (II. Conf. 44). The colour of the grain is immaterial as that is wholly a question of the bran; as it happens, however, Mr. Farrer considers the red wheats best for milling. He also advocates the selection of only hard wheats with a semi-transparent glutinous grain of

fine texture, on the ground that they are most nutritious. This is no doubt true, but the interested "dealer" and the ignorant consumer will probably long insist on the cultivation of the comparatively worthless starchy wheats.

Nature of Chaff.

Exposure to rain after ripening is, even in the unreaped wheat, apt to induce sprouting. This is much diminished in wheats that ripen with drooping heads and that have a close-lying chaff. Such sorts should be selected on this account alone; incidentally too it is to be noted that the closer the chaff lies the thinner is the bran (III. Conf. 44).

Strength of Flour.

Still another character that calls for attention in selecting wheats is the strength of the flour obtained. This, from many points of view, is of the highest importance. When we say that the strength of a wheat=60 we mean that, converted into flour, a sack (200lbs.) of this flour will absorb 60 quarts of water in making a dough fit for baking; if the strength is=45 then a sack (200lbs.) of the flour will absorb only 45 quarts of water. While only 301½lbs. of dough fit for baking can be made from a sack (200lbs.) of Vermont wheat with strength =40·6, as much as 368½lbs. can be made from the same quantity of a variety bred by Mr. Farrer which has a strength =67·4. Assuming—though this assumption is probably only approximately correct—that 5lbs. of dough go to make 4½lbs. of bread, a sack of Vermont flour will only make 271½lbs. of bread as against 331½lbs. of bread—a difference of 60¼ lbs.—made from the other. This quality, like all other qualities, can be increased by selection and rendered stable by cross-breeding (Sub-Conf. H. 1, 5).

The quality depends (1) on the amount of gluten the grain contains, and (2) the proportion in which constituent glutens—glutenin and gliadin—are associated in the gluten. The gluten-content does not by itself exhibit the strength of the flour, and the determination of the glutenin and gliadin is a tedious process. It is therefore best, Mr. Farrer thinks, from the practical standpoint, to actually mill a weighed quantity of grain, weigh the resulting mill products—flour, pollard and bran, and then make a given quantity—not less than 10lbs.—of the flour into bread, noting the exact amount of water the flour takes up in being made into dough and weighing the baked bread. The flour used must, of course, be the 'straight' flour made from the wheat, not flour that has been divided into different grades. A small roller-mill, capable of dealing with so small a quantity as 10lbs. of grain, has been invented by Prof. Maercker of Halle. It is manufactured by Ganz

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& Co. of Buda-Pesth at a cost of £50, and is recommended by Mr. Farrer as a useful possession for an Agricultural Department (SUB-CONF. H. 7).

Resistance to Drought.

Another quality capable of increase by selection is that of withstanding the effects of heat and drought. In seasons of great dryness and scanty rainfall, among heads that are mostly pinched and shrivelled some will be found with plump grains Such grains should be harvested carefully and sown in soil especially liable to become dry quickly. In this way, Mr. Farrer thinks, it is possible that strains may be developed which might prevent droughts from being so disastrous as they are in India (SUB-CONF. H. 5).

Flavour of grain.

Yet another quality to be attended to in selection is that of good flavour in the grain. Wheat-buyers in Australia attach much importance to the quality. There is every reason, Mr. Farrer thinks, to suppose that this is also an inherited quality. To possess good flavour grain has to be 'well-grown'; pinched or defective grains never possess it. The estimate can only be made by biting and tasting. The point is probably one that is worthy of attention in India, since Mr. Farrer says that, though there are exceptions, Indian wheats are rather deficient in flavour (SUB-CONF. H. 5).

Technique of selection.

§ 54. A detailed account of Mr. Farrer's method of applying the principles laid down in this chapter is contained in a report read by him at the Fourth Inter-Colonial Wheat Conference (IV. CONF. 14). The portion of the Report that describes Mr. Farrer's practice being too technical for condensation is given in full as an appendix (APPENDIX B, i. p. 78) which should be carefully studied by all who undertake wheat-growing experiments in India. In a recent letter (August 1897) to the Secretary to the Government of India, Department of Revenue and Agriculture, Mr. Farrer has added certain hints especially applicable to India; these are also given in full. (APPENDIX B, ii. p. 83), and should be equally carefully attended to.

Special varieties.

§ 55. At the various Conferences many different varieties have been mentioned and recommended as rust-resistant, while others have been similarly recommended in Inter-Conference publications. These, it is needless to say, have in many cases ultimately proved susceptible to one or other rust in one or other of the Colonies, and it is significant that the number of varieties recommended as "Rust-Resisting" at the Fifth Conference held last year (APPENDIX C. v.), even with limitations as to districts, is no greater than twelve. Five others

are recommended as "Rust-Escaping," two more as "Prolific and Moderately Resistant."

Indian wheat in Australia and Australian wheat in India.

§ 56. The experience of Australian farmers with Indian wheats has been very favourable in Queensland (SUB-CONF. J. 19, 22; K. 23), but very poor in Victoria (SUB-CONF. L. 18). And the experience with Australian wheats in India has been so far unsatisfactory. It is quite true, as the Commissioner for Settlements and Agriculture, Central Provinces, in his *Report on the Cultivation of Australian Cross-bred Wheats* says, that "the experience of one year is quite insufficient upon which to base an opinion as to the rust-resistant properties of these varieties." But the same officer writes equally justly when he points out that "it is significant that rust appeared in these plants when there was not a trace of it elsewhere in the farm."

Bearing of the Australian experience on Indian Requirements.

§ 57. The opinion of the Director of Land Records and Agriculture, Bombay, is quoted as questioning whether there is any use in attempting the growth of foreign wheats, and as considering that the Indian varieties supply ample material for improvement (*Agricult. Ledger*, 1895, n. 20, p. 71). With the latter opinion the Reporter on Economic Products expresses his entire agreement, and very justly so. The writer is inclined to agree also with the first opinion.

The Chief Commissioner of the Central Provinces points out how within his government there are at least two varieties, *mundia*, *pisi* and *bansi*, that have a reputation for rust-resistance (*Resol.* on *Rev. Admin.*, C. P., 1894-95, p. 4); there is a variety in the Western Deccan, *bakshi*, with the same reputation (III. CONF. 62), and in Bengal there is a variety, *mághi* (so-named from its ripening so early as the month of Mágh), that has been found, as a matter of fact, to escape rust very markedly in the midst of the most unfavourable conditions. There is ample material ready to hand for experiment and action on the lines indicated by the Australian experts.

Everything in the evidence afforded by the Australian literature shows that even within Australia the experiments have required to be local, and that favourable results have, as a rule, only been obtained for limited areas. That this is just as likely to be true of India needs no demonstration, and in the writer's opinion experiments with imported wheat are to be deprecated not so much because, in the light of previous experience and from the nature of the case, they are likely to be failures as because they absorb time and attention that might be much more profitably bestowed in selecting

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and creating suitable varieties from native stocks. To introduce foreign wheats in order to attempt by intercrossing to impart to Indian wheats desirable qualities that these foreign wheats possess and that no Indian wheat exhibits is of course both logical and advisable ; the introduction of foreign varieties, however desirable these may be in themselves, with a view to establishing them in India, is, so far as all the evidence available goes, a waste of endeavour. In any case, care must be taken to conduct all experimental cultures intelligently, whether the subject of the experiment be an Indian or an imported wheat. Merely to sow a series of samples for the sake of adding, at the end of the season, one more paper to a Government file in the shape of a record of the immunity from rust, or otherwise, of each, is to mistake the object of work of this kind and implies the loss of an opportunity.

The latest evidence from Europe (APPENDIX A) confirms the conclusion of Australian workers, that only by the *selection and creation* of new and rust-resisting varieties of wheat can loss from rust be hoped to be lessened. A perusal of Mr. Farrer's account of his methods (APPENDIX B) will show how much more is involved in the process of selecting and fixing types, than a mere record of the observations of a season and the preparation of a report at its close.

APPENDICES.

Appendix A.

THE PRESENT POSITION OF THE RUST-PROBLEM. [JAKOB ERIKSSON: DER HEUTIGE STAND DER GETREIDEROSTFRAGE.]

Translated from Bericht. der deutschen botanischen Gesellschaft. Jahrg. 1897. Bd. XV., Heft 3, s. 183—194.

For now more than six years a continued investigation of the rusts destructive to our cereal crops has been carried on at the experimental farm of the Royal Swedish Academy of Sciences. Results of this investigation have been published in various places;* but it is impossible to judge from these publications what the actual condition of the cereal-rust problem is, since there are some very important points, such as the spread of rust from one plant to another, and the effects of rust on the quality of seed, regarding which little or nothing has been said in the literature hitherto published. The continued and exhaustive examination of these two matters of detail is at length sufficiently advanced to permit of the publication of certain particulars.

In the pages that follow an attempt will be made, partly as supplementing already well-known results, partly too and indeed principally as the outcome of experience hitherto unpublished, to answer the practical question:—

> "Has the position of the cereal-rust problem been in any way altered as the result of the researches carried on so far, and if it has been altered, what has the change been?"

Among the more important results of this research the following may be first alluded to. It was formerly supposed that our four common cereals were affected by 3—4 species of rust-fungus. One of these species, *Puccinia graminis* Pers., was supposed to appear on all four cereals; another, *P. rubigo-vera* DC., was thought to be confined to rye and to wheat; a third, *P. coronata* Corda, was considered peculiar to oats; and a fourth, *P. simplex* Kcke (also known as *P. anomala* Rostr., and usually dealt with as a mere variety of *P. rubigo-vera*) was supposed to be similarly confined to barley. It was further imagined that all the cereals and grasses which bear one particular kind of rust are capable of infecting each other. This belief led naturally to the

* J. Eriksson und E. Henning; *Die Getreideroste, ihre Geschichte und Natur, sowei Massregeln gegen dieselben.* Stockholm 1896.—J. Eriksson; *Ueber die Specialisirung des Parasitismus bei den Getreiderostpilzen* (Ber. d. Deutsch. Bot. Ges. 1894, s. 292—331); *Ueber die Foerderung der Pilzsporenkeimung durch Kaelte* (Cent. Bl. für Bact. und Par-Kunde, Abt. 2, 1895, Bd. I. N, 15-16); *Ist die verschiedene Widerstandfaehigkeit der Weizensorten gegen Rost constant oder nicht?* (Zeitschr. für Pfl.-Krankh., 1895, s. 198—200); *Welche Grasarten koennen die Berberitze mit Rost anstecken?* (*Ibid.*, 1896, s. 193—197); *Neue Untersuchungen ueber die Specialisirung, Verbreitung und Herkunft des Schwarzrostes* (Puccinia graminis *Pers.*) (Jahrb. für wissensch. Bot., 1896, s. 499—524); *Welche Rostarten zerstoeren die australischen Weizenernten?* (Zeitschr. für Pfl-Krankheiten, 1896, s. 141—144); *Studien ueber den Hexenbesenrost der Berberitze* (Puccinia Arrhenateri *Kleb.*) (Cohn's Beitr. z. Biol. d. Pfl. Bd. 8, s. 1—16); *Vie tente et plasmatique de certaines Uredinées* (Compt. rend. 1897, 1er Mars.)

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conclusion that the origin of rust on cereal crops must be mainly attributed to its spread from adjacent rusted plants, particularly in the case of *P. graminis* which affects not only our four cereal crops but a whole host of ditch-, meadow- and forest-grasses in addition.

Our ideas regarding this subject must now be altered. It has been shown that, even if we deal only with our four cereal crops, we have to enumerate no fewer than ten sorts of rust, referable to five so-called "species." Thus—

of Black-rust (*Puccinia graminis*) we have—
(1) a form on rye and barley ;
(2) a form on oats, and
(3) a form on wheat :

of Brown-rust (*Puccinia dispersa*) we have—
(4) a form on rye, and
(5) a form on wheat :

of Yellow-rust (*Puccinia glumarum*) we have—
(6) a form on rye ;
(7) a form on wheat, and
(8) a form on barley :

of Pigmy-rust (*Puccinia simplex*) we have—
(9) a form on barley : lastly,

of Crown-rust (*Puccinia coronata*) we have—
(10) a form on oats.

Such of these ten forms as are attributed to one and the same species cannot be distinguished by structural or by metric characters ; yet one does not doubt that they differ essentially. The difference is displayed in the fact that each form is exclusively limited to some special cereal and is incapable of infecting any but this particular one. Oats infected with black-rust can only spread this black-rust on oats ; rye bearing brown-rust can only infect rye, and so on. The sole exceptions to this are rye and barley bearing black-rust, which are then mutually infective, and to a certain extent also wheat with black-rust which, in rare instances, is capable of imparting the disease to rye and barley.

Of the ten known forms of rust moreover there are but two—both of them referred to black-rust, *viz.*, *forma "secalis,"* common to rye and barley and *forma "avenae,"* peculiar to oats—that are capable of appearing on other grasses ; the former may affect *Triticum repens*, *T. caninum*, *Elymus arenarius*, *Bromus secalinus*, *Hordeum jubatum*, etc.; the latter may occur on *Dactylis glomerata*, *Alopecurus pratensis*, *Milium effusum*, *Avena elatior*, *A. sterilis*, etc. The remaining eight are absolutely exclusively limited to the special cereals that constitute their respective hosts.

As a result of this new experience we are still free to suppose, when endeavouring to trace the source of a cereal-rust, that rye or barley may have become diseased by mutual infection or by infection from neighbouring rusted couch-grass, and similarly that oats may have been infected by rusted plants of *Dactylis*, *Alopecurus*, etc. As regards the remaining eight forms of rust it is, however, useless to seek for their origin among the neighbouring grasses.

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There may be some who, knowing that rust on oats can appear in consequence of infection from specimens of such wide-spread grasses as *Dactylis*, *Alopecurus*, etc., when they happen to carry black-rust, will immediately conclude that this explains the great prevalence of black-rust on oats at the present time. Such a conclusion would, however, be rash.

Were neighbouring rusted-plants the chief source of the disease, then rye and barley should also be commonly affected by black-rust since both these cereals are capable of infection from couch-grass, which is an almost constant denizen of the edges of our fields and is of all wild-grasses the one most commonly affected by black-rust. Experience shows however that, on rye, black-rust is neither so common nor so destructive as it is on oats, and that on barley black-rust is quite rare.

Nor is this all. Only last year a number of observations were made which indicated that there may be but a trifling spread of the rust-pest even in cases where one would have expected its wide extension.

One such observation, relating to the spread of black-rust from couch-grass to barley, may be particularly mentioned. On an open path in the experimental farm running past the experimental plots, a few plants of couch-grass just beginning to shoot up at the commencement of June 1894, were permitted to remain untouched, in order to admit of observations being made on the onset and development of black-rust upon them. Alongside this path with couch-grass on it lay an experimental plot under barley. On 3rd July the first spots of black-rust showed themselves on the leaf-sheaths of a plant of couch-grass; by 13th July many uredo-pustules were present.

On both dates mentioned the barley-plot, which by the 13th July had come into ear, did not, in spite of the closest possible search being made, show a single spot of rust. Twenty days later even, on 2nd August, when the leaf-sheaths of the couch-grass were quite covered with rust-pustules, the barley-plot remained remarkably clean; there were but trifling traces of rust though it still retained plenty of green stems. It should be noted too that it rained every day from the 10th to the 13th July (measured rainfall, 20·4 mm.=·8 in.) and again every day from the 15th to the 22nd of the month (measured rainfall, 38·7 mm.= 1·6 in).

So slight a capacity for spreading cannot but be surprising when we think how readily the spores of black-rust germinate, and consider that the incubation-period, antecedent to the appearance of a new crop of pustules, amounts only to about ten days.

It is somewhat astonishing to find in connection with the spread of these rust-fungi from one plant to another that the uredospores, though quite alive, should be distinguished by a special reluctance to germinate, yet such is undoubtedly the case. An instance of this is the yellow wheat-rust (*Puccinia glumarum* forma *Tritici*), the most destructive wheat-rust of Sweden and probably also of the other countries of Northern Europe. Here the power to spread shows itself to be exceedingly trifling even as between different sorts of the same cereal, indeed even between different strains of one sort. No one can have failed to notice, when walking about mid-summer through an experimental field in which different kinds of wheat are being grown, that this or that sort may have been so badly attacked by yellow-rust as to render one's clothes yellow so soon as one enters the wheat, while sorts growing hard by are practically free from rust.

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This fact was strikingly apparent in the experimental farm in 1894. In several parts of the trial-field different kinds of winter-wheat were intentionally arranged so that the most susceptible should be next the most resistant ones. In one particular spot there was a plot of the highly susceptible "Horsford's Pearl-wheat" surrounded in different directions by five slightly susceptible kinds, *viz.*, "Graf Walderdorff's Improved." "Squarehead," "Hungarian White," "Blé Poulard," "White Ribband" and "Paine's Defiance."

The results with these plots for the summer were as follows:—Pustules of yellow-rust were first observed on "Horsford's Pearl" on May 11th; on June 13th, or thirty-three days later, the degree of rustiness by the rust-scale was 2 (= sparingly rusted), whereas none of the other plots mentioned showed any rust. Ten days later, on 23rd June, the rust on "Horsford's Pearl" stood at 4, the highest figure on the rust-scale (= generally rusted), while two of the adjacent plots were quite clean and the other three showed only faint traces of rust.

What were the special reasons for the very trifling spread of rust in these cases? Several may be imagined; one cause may, perhaps, be the natural unwillingness of the spores to germinate, a second may have been unfavourable weather-conditions, a third may be some character of blade-structure in the five resistant kinds that prevents the rust-fungus from establishing itself.

In order to test the question, so far as the germinating power of the spores and the nature of the weather are concerned, the following experiment was made during the time of year when yellow-rust grows best and under weather-conditions that are deemed most suitable for its spread.

Early each morning for five days in succession (between 5 and 7 A.M. on June 8th, 9th, 10th, 11th and 12th) five very badly-rusted plants were selected from the plots of "Horsford's" wheat. The plants, all wet as they were, were carried carefully to the laboratory and the germinability of the spores on all the leaves carefully tested. The record of this research, the details of which cannot be set down here, enables us to see that notwithstanding daily rain (the total rainfall for the five days was 33 mm. = 1·2 in.) and continuous cloud the number of spores that germinated was very small; so insignificant, that the germinability may in most cases be set down as =0. From this we may conclude that the natural disinclination of the spores to germinate contributes essentially to the remarkably limited spread of this species of rust, and that this disinclination is not appreciably diminished even during several days of rain.

We have now to consider the third of the possibilities indicated above; that some kinds of wheat possess a special inherent power of resisting the fungus which may explain the limited spread, and that the source of this is to be looked for in some mechanical, chemical or other difference.

Some observations made in the summer of 1896 give a clear but at the same time unexpected answer to the question. These observations were made on plants of "Squarehead" and of "Horsford's" wheat grown in pots in two different series, one at the end of June, the other at the end of July. The spore-material was taken from the open field, the first time from "Horsford's," the second time from "Michigan Bronze" wheat; on both occasions a state of high germinability was induced by cooling the material with ice. The result was that in both series of

infections rust-pustules were produced on "Squarehead" wheat, which in the open was quite rust-free, just as plentifully as on "Horsford's" wheat which in the open showed itself the most rust-liable. We see from this that a capacity for resisting rust, such as has been postulated above, is not inherent in different kinds of wheat, and that it is not by this hypothesis that the variable rustiness of different sorts in the field is to be explained.

Similar observations of the remarkably slight capability of spreading on the part now of one, now of another form of rust-fungus have already been made public,* and their number might be added to here. But for the present it may be enough to point out to the uninitiated that the part played by wind-carried spores in connection with the appearance and the intensity of rust-blight has hitherto been considerably overrated.

The statement of the thesis that eventual damage from rust does not, as a matter of primary importance, imply the constant importation of new disease-germs (spores) or the constant formation of new disease-centres, obviously alters very considerably the position of the whole cereal-rust question. One of the keystones on which the doctrine of the origin and the spread of cereal-rusts has hitherto depended, is thus, if not wholly removed, at least decidedly displaced. But if this be so, how are we to explain the fact, which still remains, that from an apparently insignificant beginning, cereal-rust is at times capable of attaining severe and destructive dimensions? We propose to examine whether already published researches cannot provide a new keystone to be inserted, if not in room of, at least alongside the displaced one.

Even in the earliest years of the investigation some observations were made that suggested the possibility of there being some other source of rust on cereals than the contagion of external origin assumed in the pathological handbooks. Thus autumn after autumn, 30 to 38 days after sowing, without any reference to whether adjacent plots had contained infective matter or not, yellow-rust regularly made its appearance on the most susceptible kinds of autumn-sown winter wheat, such as "Horsford's wheat," "Michigan wheat," etc.; similarly it appeared just as regularly, summer after summer, about a month after sowing, on those barleys of a like nature, such as "Skinless Barley" (*Hordeum vulgare* VAR. *cornutum*), sown at different times during the spring. Both the regularity and the length of the period accord badly with the theory of an external origin for the blight. From artificial infection it was found that the incubation-period is really only about 10 days, so that on the hypothesis that infection from outside may have preceded their appearance, one would have expected the rust-pustules to be earlier by 1—2 weeks according to the abundance of infective material in the neighbourhood and to the nature of the weather at the time.

Another striking observation, bearing on the nature and mode of appearance of this rust, was made during the autumn of 1892. In a long experimental plot extending in a south to north direction, sown with "Landreth's hard winter-wheat," a kind very susceptible to yellow-rust, the northmost and best lighted part of the plot became much affected by yellow-rust about six weeks after it had been sown, while the southern portion of the plot, extending to a wood by whose

* See particularly J. ERIKSSON, *Neue Untersuchungen* (Jahrb. für wissensch. Bot.: 1896, s. 511 folg.).

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trees it was partially shaded, was far less rusted; finally the end-furrows, which the sun barely reached at any period of the day, were almost altogether clean. A similar phenomenon was also observed during the same autumn in the experimental field in a small plot one corner of which was very much shaded by a tall ash. The more shaded the plots were, the less was the rustiness, though the time of sowing, treatment of the soil, etc., were the same. And along with diminished rustiness there was in both cases a taller and more slender habit of growth in the shaded than in the exposed plants. This observation is also wholly incompatible with the theory of external infection because under that hypothesis rust should have been worst in the shaded portion of the field owing to the moisture-conditions being there more decidedly favourable for the germination of the spores and the blade-structure more suitable for the penetration of their filaments. The observations, however, showed just the reverse.

It would be much too tedious to give a detailed account of the many experiments that have been made during the past five years and that bear on these two observations; regarding the definite relationship between the appearance of yellow-rust and time of sowing, and regarding the varying intensity of the rust according to the varying extent to which the portion of the field is exposed to light. The first observation afforded an opportunity of ascertaining—and experiments were devoted exclusively to this end—whether it may not at times, and possibly not so very rarely, happen that the source of the disease is present in the plant itself, perhaps in the seed-buds; and whether what really chiefly influences the intensity of the disease may not be the varying extent to which the existence of the fungus in the host-plant is favoured in different years by external circumstances. The details of these experiments will be given in a paper that is about to be published. In the meantime only the general course of the experiments will be indicated here by means of their actual results.

There seemed to be two ways in which the foregoing question might be decided. The one was that of experiment—to ascertain by conclusive trial whether rust is capable of appearing on such plants as are protected against any external infection throughout their growth; the other was that of anatomical investigation—to find whether any inherent disease-substance, if such a thing may be imagined, can be shown to exist.

These experiments were conducted according to two essentially different plans. The first method was as follows: At the commencement of spring, so soon as the snow had melted but before the faintest trace of yellow-rust could be detected, a number of outwardly perfectly normal young shoots were selected from a plot of wheat highly susceptible to yellow-rust. The young shoots were introduced into long spacious glass-tubes that were firmly fixed to stakes in the ground, and the shoots were allowed from that time onwards to grow inside the tubes. The tubes were stoppered with cotton-wool above and below to prevent access of spores from without, and in addition a small metal cap was adjusted above the upper end as a protection against rain. Experiments of this kind were conducted during 1893 and 1894. In the latter of these seasons, when the weather was more suitable for the development of yellow-rust and at the same time the arrangements for the experiment were more satisfactory, there came a time when rust, which appeared moreover on the plot also, was quite abundant on several of the selected stems.

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From this it was clear that an outbreak of yellow-rust, at any rate on certain sorts of wheat, may be due to infective-material already present in the plant itself. But whence then is this infective-material derived? It is possible to suppose that it may have found its way into the tender sprout during the autumn preceding as the result of infection by germinating winter-spores that happened to be in the neighbourhood of the seed; it is, however, also conceivable that the seed had inherited the disease from the parent plant.

To decide this question a different experiment was devised. The plants during their growth were partly protected from infection from without, partly grown in soil from which all harmful infective-material had been removed by sterilizing. Experiments of this nature were commenced in the summer of 1892 and have since then been annually repeated in specially constructed culture-frames which may be spoken of as isolation-frames. The frames are from half to quite a man's height and have usually been quadrilateral. The glazed sides have been fixed in wooden corner-posts. The passages below for the entrance, and above, for the exit of air, have had a layer of cotton-wool inserted so as to keep out all infective-material and an iron roof has been fixed above the frame to keep off the rain. Under the frame has been placed an experimental tray filled with sterilized earth in which to grow the plants, the soil in the frame being watered with distilled water introduced through one of the corner-posts by means of a metal pipe. In the very first year of experiment (1892) it became clear that the solution of the foregoing question was to be by no means so easy as one might have anticipated. The abnormal conditions under which the trial-plants were developed in these culture-frames—abnormal in the first place because of the constant high temperature and again because of the diminished access of light, caused the plants to grow more or less unnaturally: they were taller, more slender and paler than those grown in the open. It has already been remarked that varying degrees of exposure to light in different parts of the field suffice to induce a difference in the growth of the plant and in the amount of rustiness; it has besides been always well known that the differences in the weather of one year as compared with another have been enough to make one year a rusty year and another the opposite. All the more then must the unnatural conditions that prevail within the culture-frames affect the issue of the struggle, which we have to suppose is always going on between the host-plant and its parasite! In the very first year the event proved that in this struggle victory lay with the host-plant; in absolute agreement with the condition of affairs in shaded cultivated-patches, not a trace of rust appeared within the frames.

In the years 1892 and 1893 an attempt was made, partly by shading, partly by vigorous ventilation, to induce a natural habit of growth in the plants under confinement. Neither method, however, appeared sufficient. The shading still further diminished the access of light and induced a more unnatural habit of growth than ever. Vigorous ventilation, which was tried in 1893 by means of a wind-vane driven by a steam-engine, on an experimental area that included 13 culture-frames, certainly lowered the temperature sufficiently so long as the sky was clouded; as soon, however, as the sun shone out the temperature in the frames rose 2°—3° above that of the air outside and remained higher even when the velocity of the wind-vane was increased. The plants still grew unnaturally and no rust appeared.

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In 1894 positive results were for the first time obtained in a trial-frame —a round glass-cylinder half a metre (about 20 in.) high. The plants experimented on were of the race of barley, highly susceptible to yellow-rust, known as "skinless." On the second blade of a plant, reckoned from below, yellow-rust pustules at once appeared in 4—5 parallel lines together 10 mm. long, and on the fourth blade of a second plant in 2—3 lines 30 mm. long, while finally black-rust pustules appeared on a third plant, on the sheath of the third blade at a height of 30·5 cm. (about a foot) above the base of the glass-cylinder.

In the summer of 1895 a new plan was adopted. In the quadrangular experiment-frames the three sides looking east, south and west, respectively, were made of double glass panes and during the day, as long as the experiments lasted, an unbroken stream of ice-cooled water was made to pass between these panes. It was found that by this means the temperature in the frames could be reduced at will to below that outside, even in bright sunshine. Unfortunately, however, this reduction of temperature was accompanied by greater diminution of light than in the case of frames with single sides, particularly as the frames were only half a man's height and the roof besides threw a shadow. In consequence of this deficiency of illumination the plants became slender and pale and yellow-rust appeared only in one of the frames. On one of five plants of "Skinless" barley grown in that frame yellow-rust pustules appeared about seven weeks after sowing, first on one blade, and a week later on two others, all three blades belonging to the same stem.

If, however, the results obtained hitherto during the search for evidence in support of the theory that disease-matter may be present in the grain itself, are neither so numerous nor so conclusive as could have been wished, yet they are, even in their present state, of such a nature that it is worth while to take account of the interesting and important conclusions to be derived from the investigations conducted so far.

The other method of ascertaining the existence of internal disease-material was that of microscopic examination. All endeavours to trace in this way any such internal disease-material were at first unsuccessful; this has been the experience of all who have hitherto sought for it. In the peripheral tissues of rust-shrivelled wheat-grains there occurred, it is true, as has been described elsewhere,* a copious fungus-mycelium and indeed at times a form of spore-case with germinating winter-spores. But all attempts to discover a mycelium in the embryo itself, whether latent in the grain, or passing from the grain into the embryo at the moment of sprouting, were wholly futile, and it was equally impossible afterwards to find any trace whatever of a fungus-mycelium in the young plant during the first few weeks following the germination of the seed.

It is only at the time, 4—8 weeks after sowing, when rust-pustules first appear that such a mycelium can be found; even then it is only traceable in the immediate vicinity of the pustules.

* J. Eriksson and E. Henning, *Die Getreideroste, etc.*, s. 206, etc.

App. A.

How then is the origin of this mycelium to be explained when, during the period immediately preceding its appearance, no possible source of disease is to be found in the neighbourhood either in the shape of *Aecidium*, or of *Uredo*, or of *Puccinia?*

A key to the solution of this mysterious question was obtained in the summer of 1893. When a microscopic examination is made, under a high power, of very young yellow-rust pustules on wheat-leaves, it is found that in immediate continuation of the outmost sori of a row of pustules there occur, besides the usual cell-elements, a kind of peculiar, elongated, mostly faintly curved plasmatic corpuscles. These corpuscles may occur singly or several to each cell. Some seemed to swim about freely in the protoplasm, while others seemed to have bored through the cell-wall with one extremity or when branched with several extremities and so to have sent out inter-cellular mycelial threads. When the leaves were examined at greater distances from the outer sori of a row of pustules nothing noteworthy was found; close up to the edges of these sori the mycelial network was so copiously branched that no idea could be formed as to its origin.

The observation that has just been briefly detailed, gives, as I believe, a key to the solution of the riddle. These small plasm-corpuscles, at first swimming freely in the protoplasm, constitute a phase of the fungus, the primary phase, wherein the fungus by its independent appearance makes itself visible. The fungus has for weeks, months, possibly even years previously, led a latent existence in and alongside of the protoplasm of the host-plant. This latent existence may be termed the mycoplasm-phase of the fungus and thus a kind of symbiosis, mycoplasm-symbiosis, may be indicated,—a symbiosis that is probably more intimate than any hitherto known.*

At a particular stage of the development of the wheat-stem, always provided that the conditions as to light, warmth and moisture are such as meet the necessities of the case, a dissociation takes place in the joint-life of the two symbiotic partners. The way in which they part company is this:—the fungus becomes differentiated into an independent organism, to begin with in the form of one or more plasm-corpuscles in the protoplasm of the host-plant, and shortly thereafter as an inter-cellular mycelium derived from these corpuscles. The fungus thus, if only for a short time, the few weeks necessary for the formation of spores, takes up that position in the phase already familiar to us as the mycelial-phase. The portion of the plasm-corpuscle that passes out through the cell-wall forms the inter-cellular mycelium which presently gives rise to sori, that which remains within the chlorophyll-producing cells forms the organs that are familiar to us as the haustoria, which provide for the sustenance of the chlorophyll-destroying mycelium. If this differentiation of the symbiotic partners occurs, only a few days elapse before free rust-pustules appear.

The numerous experiments and observations on which the theory just expounded is based and only a few of which have been alluded to above, are about to be published in fuller detail; when this is done some account will be taken of the theoretical and practical bearing of the doctrine.

* Compare the parasitism of *Rozella* and of *Woronina* in the cells of certain *Saprolegniaceae* according to M. Cornu (Ann. des. Sc. Nat. Bot. sér. V., Vol. XV, 1872) and to A. Fischer (Jahrb. für wiss. Bot., XIII, 1882); see also De Bary, *Vergleichende Morphologie und Biologie der Pilze* (Leipzig, 1884, s. 424).

App. B. i.

Appendix B.

I.—Mr. Farrer's Methods in Cross-breeding of Wheats.

(*Report of the Proceedings of the Fourth Conference, pages 14—17.*)

At the last Conference I had the privilege of indicating a line of action by means of which success in combating the rust pest can be secured—such a measure of success, at any rate, as is necessary to enable wheat-growing to become, as far as danger from rust is concerned, a fairly safe industry for farmers to take in hand in districts which are not too close to the coast. In order that this line of action might be entered upon, I offered to supply to such of the Governments of the different colonies as were in a position to take the matter in hand, seeds which had been produced by cross-bred wheats of the first generation from the cross, such cross-bred wheats having been made for the purpose of combining with ability to resist the rust pest suitability for our conditions and requirements. I pointed out that the diverse types which would be produced by such seeds would enable each colony to secure, by means of selection, individual plants that possess superior power of resisting rust, and fitness for its own climate and conditions, from which individual plants such varieties as we want could be made or fixed. From the, in most cases, rather meagre reports I have received in regard to the manner in which my cross-bred wheats have served the purpose for which they were distributed, I am led to think that I failed to point out sufficiently clearly what was to be expected from them, and in what manner they should be dealt with. It is my intention to endeavour to supply this omission in this paper, and to point out in detail the steps which ought to be taken for the purpose of getting such wheats as we want from my seeds. Before doing this I would wish it to be understood clearly that I myself went carefully through this work last summer, and that what I have to say has not merely been evolved from my own brain or imagination, but is the result of actual practical experience. The details I shall give, however, unfortunately do not represent the course I actually followed, but the routine I shall hope to go through next summer, when I shall endeavour to correct the mistakes and supply the omissions of last season.

Before I begin my description of the detail work of selecting the best plants for our purpose from the cross-breds, it will be well, I think, to dwell for a moment on the special difficulties that have to be overcome in making varieties which are both resistant of rust and suitable for our conditions and requirements. When, after some years of preliminary work, which I had been carrying on before these Conferences were instituted, I had become possessed of a number of varieties that were satisfactorily resistant of rust, I found they were all late sorts, and as our hot winds are apt to ripen late sorts prematurely, and before their grain has reached its full size and filled out, I saw that lateness of maturity was almost as serious a defect in a wheat for this country as its liability to rust. It became necessary, therefore, to make an attempt to combine earliness with the power of resisting rust. This, on the face of it, has

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the appearance of being a task which could be easily accomplished by crossing rust-resistant and early varieties; but when it is considered that it may be that earliness and resistance to rust are incompatible qualities, that early and late wheats are in bloom at different times, that early rust-liable and late rust-resisting sorts belong to different types, and that crosses between varieties which differ widely are on that account difficult and tedious to fix and uncertain as to the character of the types they will produce when they are crossed, it will be seen that the task is not entirely an easy one. I have found, as a matter of fact, that in breaking this new ground I have had to work largely in the dark, and to spend much time in doing such preliminary work as ascertaining accurately the different qualities possessed by the varieties I proposed making use of as parents, and the degrees in which they were able to transmit their respective qualities to their progeny. This work has now been sufficiently done with a few varieties for me to be able to feel some degree of certainty in regard to the outcome of many of the crosses I am making, but very much still remains to be done. The work I have already done, however, makes me confident that my work in the future will be more effective than it has been in the past, and that with a smaller expenditure of labour and time; while all doubts have now been removed in regard to the success which is to reward our efforts; but I can see that the full measure of success, which is necessary to satisfy me, will not come so quickly as I had at first hoped. Resistant wheats can only be made early gradually—step by step.

In order to combine the qualities of earliness of maturity and resistance to rust in one variety by means of cross-breeding, late rust-resistant and early rust-liable sorts, as I have already pointed out, have to be mated. It will be well to pause for a moment, and consider what we ought to expect from the union of types which differ so widely in these two qualities, as well as in others, such as the relative hardness, size, character of the grain, etc. What we generally see in the analogous case of the Animal Kingdom, with which we are more familiar, when parents, that are not closely similar, are united is that, if the progeny be numerous, certain individuals inherit some of their characteristics almost entirely from one parent, combined with other characteristics which they have inherited almost entirely from the other parent; while as regards the majority of their characteristics they are intermediate in various degrees between both parents; and when this happens in different degrees and in a different manner with all the progeny, it will be seen how it comes that no two individuals of the same parentage are ever exactly alike, and that the greater the dissimilarity of the parents the greater will be the difference between the offspring of the same union. I will attempt to illustrate briefly what I mean; and for this purpose will make the case as simple as I can, and apply it to the subject we are actually dealing with.

Suppose I have mated a rust-resistant late with a rust-liable early variety of wheat. The greatest diversity of types will be shown by the offspring which grows from seed of the first generation from the cross—from such seed as I am distributing. Suppose we have 100 plants growing from such seeds, which are of the same parentage. Out of this number I would expect there might be one or two—say one—which has inherited in a very high degree, possibly even in as high a degree as the parents themselves possess them, the qualities we are seeking to secure from both parents. A few more—say five—I would expect to inherit

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high rust-resistant power from one parent, associated with moderate earliness from the other ; and five more to inherit a high degree of earliness with fair rust-resisting power. The remaining eighty-nine I would expect to inherit these qualities in various degrees intermediate between the two parents ; and something of this sort is what I actually find to occur in most cases. The work, then, of the person whose business it is to make use of these 100 plants is essentially the work of selecting as many of these eleven plants as promise to fill our requirements ; and that work, as I have found out from actual experience, requires for its successful performance the closest attention, care, patience, thoroughness, and system. With regard to the first four of the these requirements I can, of course, give no help ; I can only suggest that the work must be done in the field, and that it is impossible to do it anything like properly elsewhere. It is in connection with the last requirement that I hope to be able to give some help, and that I shall now endeavour to do.

As the principal quality we want to secure in the wheats we are aiming to get is that of offering resistance to rust, it is clearly important that we should seek to reject speedily and get rid of such plants as do not possess that quality ; and as late planting is the means at our command by which rust-liability can be made to show itself with the greatest certainty, it is clearly advisable that we should plant our seed late. I do not think it advisable, however, to make this test an unnecessarily severe one, as it is not rust-liability under any conditions that we want to bring out, but rather to see what plants are rust-liable under the least favourable conditions to which they are likely to be exposed in ordinary farming. In recommending late planting, therefore, I do not think it ought to be made later than the middle of June ; a most desirable time I would consider to be during the first half of June ; and that the occurrence of rust will have been invited sufficiently for our purpose if the seeds are planted during that fortnight. As each plant has to be examined by itself for rust, closer planting in the rows than five inches from seed to seed will be found to be undesirable. A good distance between the drills is two links, or about sixteen inches. When they are that distance apart the work of examining the plants can be done with comfort.

After sowing, and until the plants begin to head, little work need be done beyond keeping down the weeds and occasionally breaking the surface of the ground with a Planet Junior or other hoe. A close study of the plants, however, during this period will often yield much that is of interest, and varieties can then often be separated by differences which cannot be seen at other times ; but it is not until the plants begin to head that the work of selection begins.

The first thing to be noted in a drill of cross-breds is what plants are the first to come into ear. Such plants I am in the habit of marking with a black tie made from a strip of any cheap material that does not lose its colour from the weather and tears easily. The plants which show ears the first are not always the earliest to ripen or the most desirable ; and in some cases in which the presence of a black tie shows that the time between heading and ripening has been long, the marked plant is rejected on that account. It would do at least equally well to mark the first plants that come into flower, instead of those that head the first ; but in my own case it is more convenient to mark the latter. If any plant heads much earlier than any others in a drill, my custom is to mark it

with two ties, and the next early ones with one tie. I generally mark about six plants in a drill for earliness in heading. App. B. i.

The time rust begins to appear is generally a few days after the plant has gone out of bloom. It is early enough, however, to make the first examination for rust about a fortnight after that time. It is probable that, in the first examination, only the lowest leaves will be found to be affected. If most of the plants in a drill are found to have rust on them, then those that are clean should be marked by a tie of a distinct colour. If instead of a few plants being clean, few are found to be rusty, then the rusty plants should be pulled up, and got rid of at once, and none marked.

Ties of different colours should be used for marking in each examination of a drill; but the same colour should be used for the same examination in all the drills—that is to say, if pink be used for the first and chocolate for the second examination for rust in a drill, these colours should be respectively used for the first and second examinations for rust in all the drills. In every case the date of examination, the number of plants marked, and all particulars which may be wanted, such as the degree of freedom from rust each particular colour is a record of in each drill, should be entered in a field-book at the time of examination. After this, until the plants begin to ripen, examinations for rust should be made at intervals of about a week. These examinations will disclose the fact that in general the first parts of the plant to be attacked are the lowest leaves, next the middle leaves, after that the upper leaves, next the leaf-sheaths, and last of all the stalk or the part of the straw between the highest leaf and the ear. Very few plants, indeed, unless the season be one in which rust is remarkably scarce, escape having some rust on the lowest leaves; in a few more the middle leaves remain clean, while the number in which the upper leaves remain unaffected is comparatively large. It is for this reason that, in passing plants for freedom from rust, I draw the line above the leaves, and consider all plants which, in a season when rust is ordinarily prevalent, have the straw (leaf-sheaths and stalks) entirely free from rust to be satisfactorily clean. In selecting, however, the most desirable plants from which to fix varieties, I should, of course, give a decided preference to those with ties on them showing that their leaves had remained rust-free, as well as to those which appeared to possess the most desirable qualities in other respects. Periodic and fairly frequent examinations for rust, and coloured ties to mark the results of such examinations, are quite necessary, because rust that is on a plant one day may have been washed off by rain on the next and because it is frequently impracticable, if not impossible, to tell with certainty after it is ripe whether a plant has been affected with rust or not.

The last examination for rust should be made when the earliest plants are beginning to show signs of ripening, or when the stock is beginning to change its colour. In this examination two ties should be used, one (dark-blue is the colour I use for this purpose) to mark those plants that have their straw entirely clean, and the other (red is my colour for this) to show those that are the first to ripen. If most of the plants in the drill have clean straw, I pull up the rusty plants, and enter in my field-book that all the plants left had their straw clean at this examination. If any of the plants are markedly earlier than all the other plants in the drill, I mark them by two red ties, and the next earliest ones by one. In all cases I mark about half a dozen of the earliest plants in a drill

FUNGI.	Mr. Farrer's Methods in

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containing from eighty to 100. In selecting the earliest ripening plants, I mark those whose stalks change colour first. It is well, however, to be careful and to use discretion in this matter, as it frequently happens that plants ripen early because they are diseased. The appearance of the plant, and especially the manner in which the ears have filled, will show fairly well when this is the case. Plants that have ripened early because they are unhealthy should, of course, be rejected.

If the above system of marking has been carried out, the work of harvesting will be easy, and can be done quickly. One detail, however, which is essential, and should be continued in harvesting each generation until the variety is fixed, is that the plants be harvested separately, however much alike they may be outwardly, for I have frequently found that plants which are exactly alike, and had for that reason been placed in the same bundle, have differed widely in the character of their grain. It is easy to keep the plants separate by tying each into a bundle by itself. Care, however, must be taken to place the tie which goes round the bundle below the coloured marking-ties; and for this purpose the marking-ties should be slipped up the stalks to which they are attached before the ties are placed around the bundle. The several bundles from the same drill should be made into a single large bundle, and a label on which are recorded the parentage of the plants, the number of the drill from which they were taken, the character of the straw, etc., attached to it. If any plant that is harvested differs widely from the other plants which were taken from the same drill in the character of its straw or in its habit of growth, the fact should be recorded on a special label which should be attached to its own bundle. In practice, however, it is not very often that I have had occasion to do this. The large bundles should be provided with a loop by which they may be hung up.

In dealing with each drill only a few of the most desirable plants are, of course, harvested. Some of the plants, which the coloured ties on them show to be desirable as far as resistance to rust and earliness are concerned, have now to be rejected on account of other faults. It may be because they have poor or bearded heads, or because their chaff is too thin or too loosely attached to hold the grain, or because the straw is brittle or weak. It will be well, also, in harvesting to look out for plants that appear only to have escaped rust because, from being unhealthy, they have been too deficient in sap for the parasite to thrive on them. Such plants, which are by no means uncommon, are betrayed by their pinched ears. They should either be rejected, or, if harvested, should be regarded with suspicion and the fact noted on a label attached to them. In regard to the time of harvesting it will be better not to do it too soon after the plants are ripe. If they are left for a week or two exposed to the wind and weather, faults in their straw become more apparent, and a better opinion can be formed of their ability to hold their grain.

If the process I have attempted to describe has been systematically and thoroughly carried out, and if the bundles can be put away in a place where mice cannot get at them, the thrashing may be deferred until shortly before the seeds are wanted for planting; for it is better, I believe, to allow the grain to remain in the ear for some time than to thrash it out at once. The history of the different bundles has been secured; for it is recorded on them by the coloured ties and by the labels attached to the large bundles, and can be transferred to the envelopes in which the seed is placed when bundles are thrashed.

II.—Mr. Farrer's Suggestions as regards India.

(*From a letter addressed to the Secretary to the Government of India, Department of Revenue and Agriculture; August 1897.*)

I have much pleasure in forwarding to you . . . . . a number of wheats which have been selected from my collection as being likely to prove suitable for the climate of India.

Most of the samples sent are of cross-breds made by myself, and many of them contain blood of Indian varieties—in some cases indeed the blood of Indian wheat predominates. Such crosses have generally been made with the object of securing the good qualities of the Indian varieties in combination with either (1) better straw, (2) superior rust-resistance, or (3) the quality of producing strong flour—that is to say, flour which will make a large quantity of bread. Some of the cross-breds sent contain nothing but the blood of weak-flour wheats such as are at present almost exclusively grown in Australia: wheats of that character are indicated on the packets containing them to be such; and although I would certainly not recommend them, on account of the inferior strength of their flour, as well as, in general, their liability to rust, I have thought it well to send samples of such wheats, if it only be for the purpose of furnishing contrasts which will make more prominent the good qualities of more desirable sorts. On each packet of wheat sent, I have in general written what I believe to be its milling quality *as regards the strength of the flour made from it.* Wheats which have a milling quality denoted by 1 are supposed to have, when they are grown here (New South Wales), a strength of 60 or above—that is to say, a sack of flour (200 lbs.) made from them will absorb 60 or more quarts of water in making dough fit for baking. In a similar manner a wheat of milling quality=2 is supposed to have a strength of between 55 and 60. The following table will give my scale shortly and clearly:—

A wheat of milling quality=1, gives flour of strength 60 or more.
„ „ „ „ =2, „ „ from 55 to 59 inclusive.
„ „ „ „ =3, „ „ „ 50 to 54 „
„ „ „ „ =4, „ „ „ 45 to 49 „

I do not think that any wheats of less strength than 48 have been sent: and when I tell you that 48½ is the average flour-strength of the wheats grown in Australia, you will see that the wheats sent are mostly much better than over average. In cases when a single (P) is attached to the flour strength given, it means that I have good data through its parents for the opinion I have given: when two queries (PP) are attached, my data are not so satisfactory. When I have written on a packet '1st generation,' the meaning is that the contained sample has been taken from plants grown from seeds which were made by artificial impregnation: in such cases nothing whatever has been done of selecting for the purpose of making varieties, and there will be the maximum amount of variation amongst the plants grown from such seeds.

In no case would I expect results worthy of attention to be secured the first year the seeds are planted. The work to be done the first year is to plant the seeds in drills (rows) about 16 or 18 inches apart and six

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inches or even more apart in the drills. At the first harvest those individual plants (3 or 4, or in exceptional cases fewer or more) from each drill which have shown excellence as regards freedom from disease (most especially), vigour of growth, habit, ability to resist — to produce good ears filled with plump grain in the face of heat and droug ht— productiveness, time of maturity—in fact as regards all such qualities as cause a wheat to be valuable for your (Indian) climate, should be carefully harvested by themselves. This can best be done by adopting a system of previously marking the plants while they are growing: and a good method of doing this marking is by tying to the plants strips of a light fabric (print, etc.) of different colours and patterns, always using the same colour or pattern to mark the same quality. These ties should remain attached to the plants until they are harvested and indeed until they are thrashed. They will then serve as records of the qualities which were shown by the plants during their growth and be useful in making final selection and in making notes on the packet in which the seeds are finally stored. Each selected plant ought to be harvested by itself, and the seed from it planted in a drill of its own. This rule ought never to be departed from even, and especially, in dealing with plants which are apparently exactly alike, until a fixed type has been secured. If the selections have been made carefully and judiciously, the second year will most likely show that one of the selected plants is better able to transmit its good qualities than the others. Attention should be specially paid to the progeny of this plant, and selections be made again of the best plants amongst them. By being careful to harvest selected plants singly right up to the time when a uniform type has been secured, I find that varieties can generally be obtained in three or four generations, and occasionally even in two. If the work of making varieties be done carefully and systematically, I have confidence in expressing an opinion that you will be able to make, from some of the cross-breds I am sending you, varieties which will be suitable for your climate, and more than that, which will possess sufficient power of resisting rust and the effects of dry weather and heat to be of value to you on that account. If instead of growing varieties of wheat which have originated no one knows how, and have originally commended themselves by the possession in a conspicuous degree of some one quality, either of productiveness or of beauty of grain, or of some other excellence, farmers had in the past been in the habit of cultivating varieties, which had been made systematically with the object of securing rust-resistance associated with the other qualities of a good wheat, I have no doubt (I say this cautiously and deliberately after having given close attention to the subject and experimented for 10 years) that the rust-pest would long ago have lost its terrors, and that they would be in a position to encounter the conditions of a rusty season without fear of an appreciable diminution of crop. . . . . The breeding, then, of rust-resisting varieties of wheat by mating varieties of good constitution but of unlike types, and in making varieties selecting *in the localities for which the varieties are wanted* from the varying progeny of such crosses, those plants which show themselves to be most highly rust-resistant, constitutes in my opinion a rational and efficient solution of the rust-problem, and probably the only practical solution.

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Cross-breeding of Wheats. (*D. Prain.*

FUNGI.

App. B. ii.

I will bring before you yet another matter on account of its probable utility to you. For many years I have been in the habit of receiving wheats from foreign countries, and have noticed that if I plant the imported seed in a drill, while most of the plants will generally show conspicuous unfitness for our climate, I can generally nevertheless by careful examination find in a drill one or more plants which are free or relatively free from disease and have grown fairly well. By following the custom of planting the seeds from such plants only, I find I have almost invariably been able to secure quickly rust-resistant and acclimatised strains of many (probably of most that I have considered worthy of attention) of the varieties I have introduced. The principle appears to be indicated by this, that when a variety of a domesticated plant, which is reproduced by seed, is fixed in any locality or country, it is only fixed in regard to the conditions of that locality or country; and that removal to a fresh climate makes prominent differences between individuals which had before remained unseen. It is from this principle that I have formed an opinion that whenever seeds of a domesticated or even of a natural variety or species of plant are brought from a foreign country, they should in the first instance be planted in drills in such a manner that each plant can be examined, and that a process of fixing a variety afresh for its new home should be gone through. If this were done, I think the work of acclimatising plants would be made quicker and more successful. This principle I would apply to all plants propagated by seeds, and would even make use of it in transferring valuable wheats from one part of your country for trial in another.

FUNGI. Report of Committee,

Appendix C.

REPORTS IN COMMITTEE OF THE AUSTRALIAN INTER-COLONIAL WHEAT-RUST CONFERENCES.

I.—Report of Committee, First Conference.

The Committee appointed by the Conference to draw up a series of resolutions have considered it important in the first place that the magnitude of the damage occasioned by attacks of the rust fungus on wheat should be clearly and fully recognised. The loss can of course be estimated only approximately, but all the estimates indicate that it is a very serious one. During the last season, South Australia seems to have suffered most, estimates having been made in that colony showing a total loss in one season of about £1,500,000. In Victoria the estimates similarly indicate a loss of about £750,000. In New South Wales the loss has been estimated at £100,000, in Queensland at £20,000. For Tasmania no estimate is forthcoming, but the total loss suffered by the five colonies during the past season must have been not far short of £2,500,000 sterling.

For a proper understanding of how this loss arises, and for an intelligent application of preventive measures, it is necessary that the nature of rust and of the conditions favourable to its development should be generally known amongst wheat-growers. To this end a short description of the disease, illustrated by diagrams, is appended to this report.* From that description it will be gathered that the rust is a microscopic fungus, similar in its main characters to the ordinary green mould that grows in cheese and to the mildews which are commonly found in damp places on objects of every description. The rust fungus grows mainly in the tissues of the blade and the stem; it also attacks the ear, but does not, so far as at present known, directly attack the seed. By absorbing, however, the sap of the plant for its own use, it deprives the grain of its necessary nourishment, so that the seed matures in a pinched and shrivelled condition. It is stated by some authorities that when the parasite attacks the ear the wheat grain becomes more shrivelled than when only the stem and the leaves are attacked. Like all other fungi, wheat rust is propagated by spores or germs, which are produced in countless numbers, and some of which remain in the straw and the ear, some cling after threshing as dust to the seed; and some being carried about by the breeze, lodge in the soil or on other plants. There are two kinds of these spores, namely, the red ones which quickly germinate, and are the means through which the pest having once broken out is able to spread with its characteristic rapidity through an entire crop—and the black ones, known as resting-spores, which do not appear until about harvest time, and remain a whole season before they bud forth in new life; it is by means of these latter that the fungus under ordinary conditions is continued from season to

* As this subject is fully gone into in Chapter II of the *précis*, entitled "the Rust-problem," it is not necessary to reprint the description referred to.

season. The conditions favourable for the germination of these spores are the conditions favourable for the growth of almost all such fungus pests, namely, a warm, damp, still atmosphere. Any circumstances, such as an outbreak of warm weather immediately succeeding rain, such as damp ill-drained swampy ground, such as the shelter of thick hedges, and so on, which lead to the establishment of these conditions, are favourable to an outbreak of rust. The spores, as has been already observed, are carried about on the breeze, so that they become lodged on various plants. They do not, however, flourish on all plants; but on barley, oats, wild oats, canary grass, and many of the ordinary grasses they are known to thrive. Hence in devising preventive measures against rust, it is not sufficient to take into account only the circumstances which attend its attack on wheat. The fact that the circumstances leading up to an outbreak of rust are various, will explain many of the apparent discrepancies in the observations of practical wheat-growers, and will render easily explicable the conflicting evidence that is forthcoming. For it will be readily understood that in some cases weather conditions favourable to the rapid development of rust may not appear until late in the season, in which case early sown crops will, to a great extent, escape. This in most districts is the general experience. But, on the other hand, the favourable weather conditions may perchance fall very early in the season, and be succeeded by very unfavourable weather conditions; in such a case the early sown crops would suffer most. Or it may be that, in some seasons, while the conditions are favourable to the growth of rust, they are also favourable to the development of rust-resisting power in the wheat, or *vice versâ*. And also it will be understood that since the circumstances leading up to the conditions favouring the development of rust are various, so the measures taken to prevent an outbreak must be various. No one measure, no one specific, should be expected to be universally successful in its application. Past experience, however, has already brought to light and fully tested some important measures which may with advantage be immediately adopted. Experience has also shown the necessity of obtaining definite and reliable facts concerning the utility of various other measures, not yet fully tried, but which circumstances seem to indicate as being of a more or less promising character. It will also be apparent from the general tenour of the evidence that the devising and practical application of methods for coping with the rust pest will be a work of time and the result of continuous earnest effort. There will be no royal road to success; but, like all great improvements, it will be the outcome of gradual progress, and of the labours of many workers.

App. C. i.

With these considerations before them, the Committee recommends the following as a report, which may be adopted by the Conference:—

This Conference, viewing with alarm the continued ravages of the rust pest in wheat, and believing it expedient that the various Australian Governments should use every legitimate means of assisting in the prevention of these ravages, submits the following resolutions:—

(1) In view of the very general experience that early sown wheat frequently escapes entirely free from rust at times when late sown crops are greatly damaged thereby, and that in almost all cases it is considerably less attacked than late sown wheat, this Conference recommends that early sowing be adopted in all cases where applicable. In making this recommendation, the Conference does not overlook the fact that in some years, owing to unseasonable weather, early sowing is impracticable,

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but at the same time recognises that it may be adopted in many cases where late sowing is now the practice.

(2) This Conference believes that cutting the wheat crop when the grain is in the dough stage is at all times desirable, but that in a rusted crop the practice, when applicable, is specially to be recommended as a means of securing a heavier yield and better sample.

(3) This Conference, fully believing that no such cereal as rust-proof wheat has yet been discovered, but that, as shown from experiments already carried out by importing different varieties from countries outside the Australian Colonies and by carefully selecting within the colonies, certain kinds have proved to be constitutionally able to resist to a considerable extent the ravages of this pest, recommends a continuance of this work of selection and importation, with a view to securing varieties most likely to prove remunerative to the wheat farmers of the various colonies.

And, it having been found, from evidence submitted to the Conference, that certain varieties of wheat believed to be rust-resisting when grown in one locality have succumbed to the pest when grown in another locality, this Conference considers that it would not be justified in specifying any particular varieties as possessing rust-resisting qualities under all conditions.

(4) Resolved that the advisability of growing wheat upon land previously fallowed, or in succession to crops of a different order, like maize, sorghum, clover, peas, lucerne, potatoes, etc., is earnestly recommended to our farmers, on the grounds that wheat thus grown has enjoyed a greater immunity from attacks of rust than when succeeding wheat, oats, and other like graminaceous plants, and upon broader grounds of sound practical farming. The general tenour of the many facts laid before the Conference is to the effect that better farming—the practice of rotation, fallowing, and the use of farm-yard manure indirectly, by applying it to the plants which precede wheat in the rotation—has resulted not only in better crops of wheat, but noticeably lessened damage from the rust scourge.

(5) This Conference, recognising that the locus of the resting-spores of the rust fungus is chiefly the straw of the infected crop, advises that, where practicable, all infected straw, tailings, or stubbles, and all grasses immediately adjoining thereto, be carefully burned; and that, where infected straw must necessarily be fed to stock or used for bedding, all the manure therefrom be well rotted, and applied to land about to carry a non-cereal crop.

(6) The Conference is of opinion that each of the Australian Governments should institute, as early as practicable, a series of experiments on as many of the following subjects as circumstances will allow, such experiments to be continued over a succession of years, and the results to be published periodically for free distribution among all concerned :—

(*a*) The effect, as regards rust, of manuring.

(*b*) The effect of applying lime, ferrous sulphate, and salt to the soil.

(*c*) Effect of applying to the rusted crops, by means of the Strawsonizer and otherwise, solutions of ferrous sulphate, salt, sulphate of copper, and other approved antiseptics.

(*d*) Effect of different methods of cultivation.

(*e*) Effect and economical application of drainage.

(*f*) Expediency and best methods of using infected straw. App. C. i.

(*g*) Efficacy of burning all straw, weeds, and other plants in the infected field, and of using other disinfecting agencies with a view to destroying spores.

(*h*) Relative value of rust-shrivelled and healthy seed.

(*i*) Relative values of different varieties of wheat.

(*j*) Effect, as regards rust, of different times and modes of sowing.

(*k*) Effect of different times and modes of reaping.

(*l*) Investigations regarding plants that act as intermediary hosts, and regarding all plants that are affected by rust in the different colonies.

(*m*) Climatic conditions most favourable to development of rust.

(*n*) Value of any apparently suitable specific methods not mentioned in this list.

(7) The Conference affirms the value of publishing every autumn in each colony a map indicating the whole of the wheat-growing districts, illustrating the extent to which each has been affected by rust, and giving all data possible as to climatic and other conditions of past season.

(8) The Conference recommends the issuing of a series of questions to all farmers and others interested throughout the several colonies, with a view to eliciting as much individual experience as possible, and thence deducing some general laws for future guidance.

Melbourne, 11th March 1890.

II.—Report of Committee, Second Conference. App. C. ii.

The Committee of the second Conference of delegates of the Australian Colonies called together to consider the question of rust in wheat desire to record the fact that, since the last Conference, held in Melbourne in 1890, distinct advances have been made in our knowledge both of the life-history of the rust fungi occurring in Australia, and of possible methods of coping with the pest. On reference to the papers and records of experiences presented to the Conference, it will be seen that certain discoveries of an interesting nature have been made in regard to the predominance of the spring rust (*Puccinia rubigo-vera*) in the Colony of New South Wales during the past year, and a possible fourth stage of the autumn rust (*Puccinia graminis*), on a species of *Agropyrum*, the presence of germinating cells in the spermogonia of the same rust; and the grub or larvæ of a species of *Diplosis* which feeds on the rust, and may be instrumental in spreading the pest. Abundant evidence has been accumulated showing the existence in Australia of varieties of wheat which are constantly less liable to damage from rust than are other varieties. Evidence has been gathered by direct experiments, and by information received from farmers in response to questions issued to them, which confirms the soundness of the recommendations of last year's Conference in regard to early sowing, and the less liability to disease of crops grown in rotation; and it has also been shown that, as a rule, thinly-growing crops suffer less from rust in these colonies than do thickly-growing crops. In regard to curative measures—which as temporary and occasional expedients should not pass disregarded—the proper use of fungicides has been further indicated

App. C. ii.

by last year's experiments. It has been found that a solution composed of one part of sulphate of copper and 400 parts of water destroyed the vitality of the rust spore, and that a solution of 1 oz. of sulphate of iron to the gallon of water when sprayed over a growing crop at a time when rust was about to break out prevented the appearance of rust until a fortnight or three weeks later; and even if applied when the rust had attacked the plant, destroyed all outward appearance of fungus, and prevented its reappearance until fourteen days afterwards. These, the Committee submit, are evidences of real progress in the important and difficult work with which the Conference has had to grapple.

After a survey of the facts in evidence, the Conference in Committee has drafted a series of resolutions, which are now submitted for formal sanction. These resolutions are the same as those of last year's Conference, together with certain modifications and additions suggested by the further evidence gained during the past twelve months.

The series is divisible into two classes, the first embracing measures which the Committee believes may with confidence be recommended for immediate adoption, with a view to lessening the chances of loss consequent on rust. These recommendations do not refer to the adoption of any specific remedies or preventives, but rather to the general improvement and modification of existing methods of wheat-growing, and the gradual introduction of better systems of farming. The facts accumulated in evidence, as well as the experience and knowledge of the individual members of the Committee—both of those members who are engaged in wheat-growing for the market, and of those who are engaged in scientific inquiry into the subject—unmistakeably indicate that the ravages of the rust pest would be materially decreased by intelligent perseverance in the direction of these general methods. The recommendations are not offered for indiscriminate adoption, but for selection or modification according to the results of local experience. The Committee believes that if all those interested in the advancement of agriculture would cordially unite in encouraging Australian farmers and wheat-growers to persevere in the direction of these recommendations, the result would be a most important diminution of the loss resulting from rust, and a steady increase in our output of wheat.

The second class of resolutions refers to methods and subjects of inquiry recommended for the coming season.

The resolutions are as follows:—

I.—Recommendations for the immediate attention of Farmers.

1. In view of the general experience that early-sown wheat frequently escapes free from rust at times when late-sown crops are greatly damaged thereby, and that in the great majority of cases it is attacked considerably less than late-sown wheat, this Conference recommends that early sowing be adopted whenever possible. In making this recommendation the Conference does not overlook the fact that sometimes, owing to unseasonable weather, early sowing is impracticable, but it also recognises that early sowing might readily be adopted in many cases where late sowing is now the practice.

2. This Conference believes that cutting the wheat-crop when the grain is in the dough stage is generally desirable as a means of securing a better sample of grain for milling purposes; and that in a rusted crop the practice is specially to be recommended to this end. This

recommendation, however, does not refer to obtaining grain for seed, for which purpose the crop should not be cut until fairly ripe. App. C. ii.

3. This Conference, believing that no such cereal as rust-proof wheat has yet been discovered, but that, as shown from experiments lately carried out by importing different varieties from countries outside the Australian Colonies, and by carefully selecting and hybridising them within the Colonies, certain kinds have been found to constantly escape to a considerable extent the ravages of this pest, recommends a continuance of this work of importation, selection and hybridisation, with a view to securing varieties most likely to escape rust and specially adapted to the different districts of our Colonies. And, it having been found from evidence submitted to this Conference, that certain varieties of wheat, believed to be rust-resisting, when grown in one locality, have succumbed to the pest when grown in another locality, this Conference considers that it would not be justified in specifying any particular varieties as possessing rust-resisting qualities under all conditions, but provisionally recommends the following as worthy of careful trial:—Ward's Prolific, Victorian Defiance, Queensland Defiance, Red Tuscan, Belatourka, Fill-bag, Du Toits, Rattling Tom, Blount's Lambrigg, and Leak's.

4. Inasmuch as rust-resisting wheats, when grown for a few seasons in rusty districts, are liable to lose their ability to avoid the attacks of the rust fungus, this Conference affirms the desirability of establishing at as early a date as possible in suitable districts of the different Colonies, seed depôts, or stations for the maintenance and improvement, by selection and hybridisation, of the rust-resisting and other desirable qualities of seed-wheats, and for the constant distribution of standard varieties throughout the Colonies.

5. This Conference desires to record its conviction that red wheats should be brought more generally into cultivation in these Colonies, for the reason that, while they are hard and well suitable for milling purposes with modern milling machinery, they are also less liable to the ravages of rust than are white wheats. It considers that the present prevailing demand on the part of grain merchants and millers for white wheats is not based on any sound principle, and it is prejudicial to the interest of wheat-growers and bread consumers.

6. The advisability of growing wheat on land previously fallowed, or in succession to crops of a different order, such as maize, sorghum, clover, peas, cow-peas, Indian grain, lucerne, and other Leguminosæ, potatoes, mangolds, and other root-crops, etc., is earnestly recommended to our farmers, on the grounds that wheat thus grown has enjoyed a greater immunity from attacks of rust than when succeeding wheat, oats, and other like graminaceous plants, and also upon broader grounds of sound practical farming. The general tenour of the many facts laid before the Conference is to the effect that better farming—the practice of rotation, fallowing, and the use of farm-yard manure indirectly, by applying it to plants which precede wheat in the rotation—has resulted, not only in better crops of wheat, but noticeably lessened damage from the rust scourge.

7. In view of the general evidence that in the Australian Colonies, thinly-sown crops are less attacked by rust than thickly-sown crops, the Conference recommends the more general adoption of the practice of thin sowing, due regard being given to the soil, the time of sowing, and the peculiarities of the local climate.

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8. This Conference, recognising that the locus of the resting-spores of the rust fungus is chiefly the straw of the infected crop, advises that, where practicable, all infected straw tailings or stubble and all grasses immediately adjoining thereto, be carefully burned; and that, where infected straw must necessarily be fed to stock, or used for bedding, all the manure therefrom be well rotted and applied to land about to carry a non-cereal crop.

II.—Recommendations for Enquiry and Investigation.

9. The Conference affirms the desirability of continuing experiments and inquiries in directions such as are indicated in the 6th Resolution of last year's Conference. The subjects for investigation fall under the following headings :—

(*a*) The effect, as regards rust, of manuring.
(*b*) The effect of applying lime, salt and sulphate of iron to the soil.
(*c*) The effect of applying to the rusted crops, by means of the Strawsonizer or otherwise, various fungicides in solution or in powder, such as sulphate of iron, salt, sulphate of copper, Bordeaux mixture, eau celeste, ammonic carbonate of copper, carbolic acid, and thymol.
(*d*) Effect of different modes of cultivation.
(*e*) Effect and economical application of drainage.
(*f*) Expediency and best methods of using infected straw.
(*g*) Efficacy of burning all straw, weeds, and other plants in the infected field, and of using other disinfecting agencies, with a view to destroying spores.
(*h*) Relative value of rust-shrivelled and pump seed.
(*i*) Relative value of different varieties of wheat.
(*j*) Effect, as regards rust, of different times and modes of sowing.
(*k*) Effect of different times and modes of reaping.
(*l*) Investigations regarding plants that act as intermediary hosts, and regarding all plants that are affected by rust in the different Colonies.
(*m*) Investigations as to the earliest stage of wheat in which the fungus may effect an entrance.
(*n*) Investigations regarding any insects, such as the recently discovered grubs of a *Diplosis*, which feed upon rust-spores and may be instrumental in spreading the pest.
(*o*) Investigations in regard to the influence on rust of interchange of seed between suitable localities.
(*p*) The influence which the growing of the seed in hot climates has on the early maturing of wheats.
(*q*) Investigations in regard to the effect of mixture of seed on the development of rust.
(*r*) Macroscopical, microscopical and chemical examination of varieties of wheat in order to discover the characteristics of rust-resisting wheats.
(*s*) Trials of various Leguminous plants from various parts of the world, suitable for introduction into rotations in the

different districts of Australia, and especially into the wheat-growing districts of the dry interior. App. C. ii.

(*t*) Investigations in regard to standard of rustiness and in regard to some more precise method of comparing the degree of rustiness than the use of vague expressions, such as "slightly rusty," "rusty," and "very rusty."

10. Resolved, that, for experimental purposes, an inter-colonial exchange of all varieties of wheat in the Colonies be effected in time for next season's sowing.

11. It is recommended that steps be taken by the various Governments to encourage the production or improvement of implements suitable for spraying wheat crops.

12. Resolved, that, as soon as possible, experiments on a sufficiently large scale be made in the various Colonies to demonstrate the most practical method of spraying crops with suitable fungicides.

13. The Conference affirms the value of publishing every autumn in each Colony a map indicating the whole of the wheat-growing districts, illustrating the extent to which each has been affected by rust, and giving all data possible as to climatic and other conditions of the past seasons.

14. It is recommended that the series of questions set forth in Appendix I* to this report, relating to the coming season's crop, be issued to the farmers in all the Colonies; and that together with these questions, an invitation be issued to the farmers to forward specimens of wheat and other plants upon which rust is found growing, instructions for gathering samples, as set forth in Appendix II,† being issued at the same time.

15. Resolved, that draft copies of all reports of investigation and experiments which are intended for presentation at the next year's Conference, be circulated amongst the various members at least a fortnight before session.

Sydney, 8th June 1891.

III.—Report of Committee, Third Conference. App. C. iii.

At the first of the present series of Conferences, which was held in Melbourne in 1890, to consider the question of rust in wheat, it was recognised that the annual loss in these Colonies caused by the ravages of the rust fungus were very serious indeed. It was estimated that in the season preceding that Conference, namely, the season of 1889-90, the total loss from this cause in the Australian Colonies could not have been less than £2,500,000. The constant presence of a pest which annually causes such serious losses required that determined and well-considered measures should be taken for the subjugation of the pest, and justified the incurrence of an adequate expenditure for the carrying out of investigations and experiments with a view to enlarging the common knowledge of the subject and of initiating measures for lessening the ravages of the pest. At that Conference a good deal of the already existing knowledge about this subject was focussed and carefully considered; but it was seen that this knowledge was in some directions of a

* Omitted. A series of 39 questions intended to bring out more clearly the facts regarding the points enumerated in paragraph 9 of this report.

† No Appendix II is given in the original.

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vague and general character; moreover, much of the information tendered was very conflicting and not based upon precise and careful observation. Such information as was precise and well-established, was published in the report of that Conference and distributed amongst the farmers; but such information and opinions as were less certain were subjected the following season to the test of experiments conducted with as much exactness as was practicable. The influences upon the development of rust of various kinds of manuring, of treatment of the ground, treatment of the seed, different times of sowing, different times of reaping, of the variety of wheat grown, and so forth, were put to the test of experiments, which have now extended over two years. As a result of these experiments, it has been very clearly shown that, amongst those factors in the growth of wheat which are at present controllable by man, by far the most important factors relate to the times of sowing and the varieties of wheat grown. Manuring and treatment of the soil, methods of cultivation, times of reaping, etc., have an influence on the development of rust, but the influence is, generally speaking, trifling as compared with the influence of the variety of wheat grown and the time of sowing. It has been clearly shown that there are several varieties of wheat which, except under very unusual circumstances, are never seriously attacked by rust. And it has also been shown that in many districts early sown wheats of a rust-liable kind generally escape damage by rust when the same wheats sown late suffer seriously.

In view of these facts the Conference has now directed attention mainly to encouraging the growth of varieties less liable to be attacked by rust and also to early sowing. To this end it was found desirable to find out precisely what were the characteristics of those wheats which are less liable to be attacked by rust, and a step has been taken in this direction. In the first place, the following classes have been made in which to place the various wheats:—

First Class.—Rust-proof wheats, by which is meant wheats which will not permit the mycelium of rust to enter and feed on their tissues. Of such wheats there are no known examples.

Second Class.—Rust-resisting wheats, by which is meant wheats which in localities suited to their growth and under normal conditions resist at all seasons of the year either the entrance of the rust mycelium into their tissues, or its subsequent growth and outburst. Of this class many examples are known.

Third Class.—Rust-liable wheats, by which is meant wheats which under the usual conditions of growth offer no resistance to the rust. Australian wheats now mostly grown belong to this class.

Fourth Class.—Rust-escaping wheats, that is to say, wheats which, like the third class, are rust-liable, but which, if sown at the proper time, ripen so early as to be ready for harvest before the rust of an ordinary season can prevent a paying crop.

Of these two classes, the most important are the second and the fourth. The characteristics of the second class, namely, the rust-resistant wheats, have been found by thorough and close examination of twelve varieties to be as follows:—Firstly, the possession of a thick or tough skin, so tough that, although the rust mycelium may enter the plant by means of the open stomata, yet it cannot break through the skin in order to

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mature and shed its spores, so that its further development is prevented; and, secondly, the presence of a waxy exudation on the surface of the plant similar to the bloom of fruit; this waxy covering when present about the mouths of the stomata prevents the rust mycelium from entering. Wheats possessing tough skins, and especially, if possessing the toughness of skin in conjunction with the waxy bloom, may be grown under all conditions suitable to their normal growth without suffering seriously from rust. On the other hand, the rust-liable wheats, which are characterised by the possession of a thin and tender skin and often by the absence of bloom, can be grown successfully during a rusty year only in one way, namely, by sowing at such time that the plant shall be for only a short period subject to the attacks of the rust fungus. As to the proper time of sowing such wheats, no universal rule can be given. Sometimes these wheats escape rust the most when sown early and sometimes when sown late; but in the great majority of cases which have been examined by the Conference early sowing has been very much the most successful. And when, in addition to early sowing, early maturing varieties are selected, the loss due to rust becomes, taking the average of experiences, comparatively trifling. With these facts now clearly and indubitably established, one may lay down a course of action which, if judiciously pursued, will certainly in great measure do away with the losses caused by rust. Thus there are many, perhaps the majority of wheat-growing districts where, if quick-maturing wheats be sown early, they, in nine cases out of ten, escape damage by rust. If then the farmers in these districts, when they have the opportunity of sowing early, should sow such varieties as Steinwedel and Australian Glory, which are quick-growing wheats, or even such prolific wheats as Fill Bag, Rattling Tom, and Farmer's Friend which, while not being specially quick-growing, are yet able to escape rust if sown early enough, they would run little risk of loss from rust. If, however, in such districts the farmer be prevented by late rains or other causes from early sowing, then he cannot sow this class of wheat without running serious risk. He should then on no account sow these wheats, but only those belonging to the class we have described as rust-resisting, a class which embraces such well-known wheats as Blount's Lambrigg (except for coast districts), Leak's Belatourka, Victorian and Queensland Defiance, Ward's Marshall's White, Smith's Nonpareil, Medeah, Talavera, Red Californian, Town and Country, and Mummy. In those districts where the crops, whether sown early or late, are equally liable to rust, then rust-resistant wheats alone should be sown at any time.

From the above it will be understood that the principal measure recommended by the Conference for dealing with the rust-pest is the growth of suitable varieties of wheat. But this is not the only measure that needs to be taken, for it has been clearly shown that the varieties of wheat, both the rust-resistant and the early maturing, are apt to lose their desirable qualities in the course of time, and, moreover, some of those varieties which are suitable in regard to their rust-resistance and early maturing are unsuitable for general purposes owing to the possession of other undesirable qualities, and hence it is necessary that a thoroughly efficient and organised system should be established for the maintenance or improvement of the qualities of suitable existing varieties, and for the production and distribution of new and improved varieties, and at the

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present Conference, now held in Adelaide, a definite scheme of an inter-colonial character has been proposed and discussed, and recommendations made for its immediate establishment. By means of this scheme the farmers will have distributed amongst them, time after time, as occasion may require, rust-resistant and rust-escaping wheats suited to their districts, the good qualities of which wheats will have been ascertained and proved by a stringent test before distribution.

The question of the marketableness of rust-resistant wheats has been considered by the Conference. It has been said that Australian millers will not buy them except at reduced prices. Supposing such were the case, the evil would not be so great as that of the rust-pest, for it is obvious that a crop of 14 bushels to the acre of a rust-resistant wheat sold at 3*s*. 9*d*. per bushel would be a very much better return than a crop of 5 bushels or 6 bushels to the acre of a rust-damaged crop sold at 4*s*. per bushel. But some of the highest quality wheats of the rust-resistant class have been submitted to the judgment of leading millers, who have pronounced them to be of a good milling character. Many of the resistant wheats produce grain containing a greater proportion of gluten than do the rust-liable wheats, which contain, on the other hand, a greater proportion of starch. But that these hard and highly glutinous wheats produce good and nourishing flour has been shown by the Conference. Bread of good quality has been made from this flour, and there seems little doubt that such bread is more nutritious than that made from starchy wheats. Probably the best bread can be made by mixing both classes of wheat, as is now done in England. When the value of these hard glutinous wheats becomes more widely known in these Colonies, there is no doubt that a greater demand for them will spring up. In the meantime, however, it should be pointed out that there is already a large and constant market for the class of hard wheats, namely, the export market, and the only condition necessary for the export of this class of wheats is that they should be grown in large quantities, that is to say, in shiploads.

In order to draw the attention of farmers to the rust-resistant wheats, the Committee has this year drawn up a resolution recommending that special exhibits of these wheats should be made at agricultural shows and prizes offered for them, and it is a significant fact, and one which shows how the work of the Conferences during the last two years has already borne fruit, that at the agricultural show now being held at Adelaide two very fine and complete collections of this class of wheats were exhibited, and prizes were awarded. This is probably the first exhibit of the kind in any of the Colonies.

In connection with the question of the market value of wheats, the Conference recommends that the agricultural department of each Colony should take steps to establish a system of testing wheats in the laboratory and reporting their value to the farmers. Small mills for the rapid testing of lb. samples have already been invented and brought into use.

In examining the varieties of wheat now grown in the Colonies, the conviction has forced itself upon the Conference that, while in one of the great staple industries of this country, namely, that of wool-growing, the breeds of sheep are distinctly named, pedigrees kept, and the rules of breeding well known ; in the other great industry, namely, that of wheat-growing, much confusion exists about varieties and their names, and

much remains to be learnt in regard to the rules which should be followed in producing and maintaining varieties. Steps have therefore been taken, in accordance with a resolution at the last Conference, for making a complete collection of all varieties now in the Colonies so as to compare them and decide upon a common system of names, and also experiments have been commenced for enlarging our knowledge concerning rules for improving the qualities of wheats and for producing new varieties. App. C. iii.

While the Committee re-affirm their belief that the rust-pest will be subjugated mainly by action on the lines above indicated, yet they would encourage the continuance of experiments in other directions, and especially in the direction of spraying. The statements made at the Sydney Conference concerning the fatal effects of various fungicides on the germination of the rust-spores have been confirmed during the past season, but the difficulties attending the application of fungicides to wheat crops have not been wholly overcome, although progress has been made in this direction, and through the action of the Conference an important addition has been made to the machinery for applying sprays to crops cheaply and on an extensive scale.

The Committee consider it useful that questions similar to those issued last year, but shorter and fewer in number, should be re-issued to farmers during the coming season, and that returns should be called for by the statistical offices in each Colony showing the amount of loss suffered from the rust.

For the purpose of formally embodying the above policy, the Committee recommend that the following resolutions be adopted by the Conference :—

Recommendations for the immediate attention of Farmers.

1. In previous years this Conference has drawn attention under the head of "Recommendations for the immediate attention of Farmers" to certain practical rules of proved utility in checking the spread of rusts. These rules have come to the Conference as the personal experiences of individual members and through correspondence with the practical farmers and wheat-growers of every section of the Australian Colonies. Like all rules of agricultural practice, these recommendations are not to be taken as infallible; nor are they offered as specifics for the disease which the Conference has been called to combat. They no more than represent certain well-marked and clearly-defined tendencies. But while it is true that the farmer whose practices conform to these recommendations may yet be a sufferer from the rust contagion; it is absolutely certain that he will suffer in a much less degree than his neighbour who in practice ignores these dicta of the Conference. In this respect the experiences of the past season but add force to those of previous years. The Conference therefore desires, without going to the length of repeating the rules laid down in the reports of the Melbourne and Sydney meetings, to re-affirm with slight modifications the suggestions made in the reports of those meetings. Whatever other measures may be adopted by the farmers with the object of preventing the disease entirely or of arresting its further spread, the practices here suggested may not with safety be ignored. These recommendations, briefly stated, are as follows :—

I.—Early sowing and the cultivation of early ripening sorts.

II.—Harvesting rust-infected crops in the early or "dough" stage.

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III.—The growth of sorts which local experiences have shown to be rust-resisting or rust-escaping.

IV.—The growth of wheat after fallowing, or after crops of a different order, agreeable to the true principles of rotation.

V.—Thin seeding, with due regard to varieties and local conditions of soil and climate.

Prizes for Wheats at shows.

2. This Conference recognises the need of an awakened interest in the new facts bearing on rust-resistance, and believes that the agricultural shows may contribute largely to this object. We therefore urge upon local societies the importance of offering special prices for collections of wheats of proved value as rust resisters. And it is further advised that these collections be kept separate from the general wheat exhibits, and that they be plainly labelled to the end that a wide publicity be given to the general subject, as well as to the characteristics of promising sorts.

Trial of Various Wheats.

3. This Conference believing that no such cereal as rust-proof wheat has yet been discovered, but that, as shown from experiments lately carried out by importing different varieties from countries outside the Australian Colonies, and by careful selecting and crossing them within the Colonies, certain kinds have been found to constantly escape to a considerable extent the ravages of this pest, recommends a continuance of this work of importation, selection and crossing, with a view to securing varieties most likely to escape rust and specially adapted to the different districts of our Colonies. And it having been found from evidence submitted to this Conference that certain varieties of wheat, believed to be rust-resisting when grown in one locality, have succumbed to this pest when grown in another locality, this Conference considers that while it would not be justified in specifying any particular varieties as possessing rust-resistant qualities under all conditions, nevertheless particularly recommends the following, in the order given, as worthy of being grown on a large scale :—

A.—*Recommended for Growing on a Large Scale.*

I.—As rust-resistant—
(1) Blount's Lambrigg (not in coast districts), (2) Leak's, (3) Belatourka,* (4) Ward's Prolific, especially the strain known as Marshall's White, (5) Victorian Defiance, (6) Queensland Defiance, (7) Smith's Nonpareil, (8) Médéah,* (9) Talavera, (10) Red Californian, (11) Town and Country, (12) Mummy.

II.—As prolific and moderately resistant—
(1) Fill Bag, (2) Rattling Tom, (3) Farmer's Friend.

III.—As rust-escaping, if sown early—
(1) Steinwedel, (2) Australian Glory.

B.—*Recommended for further Trial on a Small Scale.*

I.—As rust-resistant—
(1) Fluorspar,† (2) Blount's Fife,† (3) Fultz,† (4) Tourmaline, (5) Niagara, (6) Improved Fife,† (7) Bega Wheat,

* Belatourka and Médéah are specially recommended for hot districts, either in the interior or on the coast.

† Of the above, Fluorspar, Blount's Fife, Fultz, Improved Fife, and Hornblende are not recommended for coast districts.

(8) Anglo-Australian* or Anglo-Canadian, (9) Manitoba, (10) Square-headed Sicilian, (11) Sicilian Baart,* (12) Clarke's Rust-proof, (13) Hornblende,† (14) Pugh's Rust-proof, (15) Summer Club. App. C. iii.

II.—As rust-escaping—
(1) Jacinth, (2) Quartz, (3) King's Jubilee, (4) Square-headed Sicilian, (5) Early Para, (6) Australian Wonder.

Recommendations for Government Action.

4. RESOLVED.—That it is desirable that a practical system for the production and distribution of rust-resisting wheats suitable to different districts should be immediately established, and this system should, subject to modifications needed by each Colony, be conducted on the following lines:—A central station for each Colony for the preliminary testing of new wheats introduced into the Colony, for the production of new varieties by cross-fertilisation and by selection, and for the distribution of suitable wheats thus obtained to representative districts of the Colony; to be there subjected to a sufficient test and, if necessary, fixed in their characters by farmers and others competent for the work, and that such wheats as pass satisfactorily this test should then be distributed to the farmers around in such a manner and by such agency as would be most suitable to the conditions of each Colony.

Nomenclature.

5. RESOLVED.—That in connection with the inter-colonial exchange of seed now being carried out steps be taken for the proper naming of the different varieties of wheat, and that Dr. Cobb, Mr. Farrer, Professor Lowrie, Professor Shelton, Rev. H. E. Thompson, and Mr. Pearson be appointed a committee for the purpose.

Experiments.

6. The Conference re-affirms the desirability of continuing experiments and inquiries in directions such as were indicated in the sixth resolution of last year's Conference. The subjects for investigation fall under the following headings:—

(*a*) The effect, as regards rust, of manuring.
(*b*) The effect of applying lime, salt, and sulphate of iron to the soil.
(*c*) The effect of spraying.
(*d*) Effect of different modes of cultivation.
(*e*) Effect and economical application of drainage.
(*f*) Expediency and best methods of using infected straw.
(*g*) Efficacy of burning all straw, weeds, and other plants in the infected field, and of using other disinfecting agencies with a view to destroying spores.
(*h*) Relative value of rust-shrivelled and plump seed.
(*i*) Relative value of different varieties of wheat.
(*j*) Effects, as regards rust, of different times and modes of sowing.
(*k*) Effect of different times and modes of reaping.

*Anglo-Australian and Sicilian Baart are recommended for coast as well as for interior districts.

† Of the above, Fluorspar, Blount's Fife, Fultz, Improved Fife, and Hornblende are not recommended for coast districts.

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(*l*) Investigations regarding plants that act as intermediary hosts and regarding all plants that are affected by rust in the different Colonies.

(*m*) Investigations as to the earliest stage of wheat in which the fungus may effect an entrance.

(*n*) Investigations regarding any insects, such as the recently discovered grubs of a *Diplosis*, which feed upon rust spores and may be instrumental in spreading the pest.

(*o*) Investigations in regard to the influence on rust of interchange of seed between suitable localities.

(*p*) The influence which the growing of seed in hot climates has on the early maturing of wheats.

(*q*) Investigations in regard to the effect of mixture of seed in the development of rust.

(*r*) Macroscopical, microscopical, and chemical examination of varieties of wheat in order to discover the characteristics of rust-resisting wheats.

(*s*) Trials of various Leguminous plants from various parts of the world, suitable for introduction into rotations in the different districts of Australia, and especially into the wheat-growing districts of the dry interior.

(*t*) Investigations in regard to a standard of rustiness and in regard to some more precise method of comparing the degrees of rustiness than the use of vague expressions such as "slightly rusty," "rusty," and "very rusty."

(*u*) Determination of the particular kind of *Puccinia* affecting the crops in different districts and the damage done by each.

(*v*) Investigations to determine the presence or absence of the rust fungus in the seed.

(*w*) The effect, as regards rust, of the treatment of the seed before sowing.

Questions to Farmers.

7. RESOLVED.—That the following series of questions on rust in wheat, relating to the coming season's crop, be issued to the farmers in all the Colonies :—

At the Inter-Colonial Conference on Rust in Wheat, held in Adelaide in March 1892, it was recommended that the following questions be submitted to the wheat-growers of Australia. Special attention is called to the fact that the questions cover in part the same ground as those issued last year. It is hoped that the experiments and discussions resulting from the questions of last season have given rise to more valuable opinions among wheat-growers, and that therefore all growers who undertake to answer the questions here submitted will be even more particular than formerly to give as complete and exact information as possible, even though information of a similar kind was forwarded last year. It is requested that the answers to these questions be sent in not later than the 21st January, 1893 :—

Name_____

Address of farm_____

Parish_____

County or Division_____

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(1) How many acres of your land were under wheat this season? App. C. iii.
(2) What portion of this was damaged by rust, and what was the loss per acre on that portion?
(3) What kind of season have you had this year?
(4) Give the date when the first speck of rust was observed in your crop.
(5) Give the date when the rust spread throughout your crop so as to do damage.
(6) State the kind of weather at this time.
(7) What was the time of sowing the seed? Was this early or late for the district?
(8) What kinds of wheat did you grow this year?
(9) What varieties have you found this year most affected and least affected by rust?
(10) Did the rusty crop start thinly or thickly on the ground?
(11) What has been your experience this season with shrivelled seed as compared with plump seed?
(12) Did you cut any of your rusted crop in the dough stage? If so, what were the results as to yield?
(13) Does wheat from colder or warmer, wetter or drier districts, suffer most from rust with you?
(14) Name any other plants, and especially grasses, upon which you have observed rust. If possible, send samples of such plants.
(15) What results have you obtained from any measures of prevention you may have tried?
(16) What kind of soil and sub-soil have you?
(17) Is there any other information you would like to give?

Publication of Reports on Experiments.

8. Resolved.—That it is desirable that reports of the coming season's inquiries and experiments in each Colony be published by the respective Governments in the ordinary departmental publications, and that an inter-colonial exchange of these reports be effected in the usual way.

Adelaide; March 12th, 1892.

IV.—Report of Committee, Fourth Conference.

Preamble.

It seems proper that this Conference should give to the public certain facts regarding the evolution of the work it now has in hand. It will be remembered that the series of Australian Conferences on Rust in Wheat, of which the present is the fourth, is the first of the kind ever held. Precedents that might serve as guides in the work that was expected of them were, of course, entirely wanting. It has been necessary, therefore, not merely to devise methods of work, but the means by which plans were given effect to had, in many cases, to be created. The Conference had no inherent powers by which it could create new facts. Until quite recently it has had to rely for its facts concerning the more practical bearings of the problem it has had to deal with upon answers to questions put forth by the Departments of Agriculture of the several Colonies. These replies were often very useful, but often they were conflicting and irrelevant. It was felt, almost from the first, that the App. C. iv.

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Conference must take steps to create a mass of experimental facts that would have an undoubted bearing upon the work in hand. To this end its members have carried out a vast and most comprehensive scheme of experiments, scientific and practical, the details of which occupy much of the volume of reports that have been given to the public. This experimental work has covered subjects of which the following are a part only :—

(1) The relation of applied manures to the spread of the rust contagion.
(2) Effect of fungicides applied in spraying.
(3) Effect of cultivation.
(4) The character of flag and straw of wheats as influencing the spread of the disease.
(5) The extent to which the rust spores adhere to seed wheat.
(6) Microscopical, chemical, milling and baking tests of wheats, made with the purpose of determining the relation of rust-resistance to known qualities.
(7) Influence of insects as carriers of rust spores.
(8) Determination of the particular kind of *Puccinia* affecting crops in different districts.
(9) Effect (upon rust) of different times and modes of sowing wheat.
(10) The creation of rust-resistant sorts by cross-fertilisation and selection.
(11) The relative value of different varieties of wheat.

In carrying out the experiments of which the above is an outline, members of the Conference have unanimously been led to the conclusion that efforts in this direction may most hopefully be turned towards the study of the wheat plant itself. We recognise that the wheat plant is naturally endowed with certain qualities, active or latent, which are susceptible of development to such a degree as to make it, to a very great extent, proof against the attacks of rust. Evidence has been presented to this Conference that, as far back as 1867, the rust-resistant powers of certain varieties have been recognised by practical farmers of the older wheat-growing Colonies. Acting upon their own success and failures, and the available facts of practical life, the members of the Conference have been led step by step, as by a common impulse, to direct their efforts, almost exclusively, to the work of bringing to light those sorts which possess in the highest degree rust-resistant power. In this way, the reports of the Conference have come to be, almost exclusively, a record of the work of its members, and latterly of efforts put forth to develop or discern this quality of rust-resistance.

The proportions this new work has assumed under the hands of the representatives of the several Colonies may be gathered from a few brief statements of facts :—The representatives of New South Wales have an experimental list of something over 500 varieties ; Victoria 315 ; South Australia, 340 ; Tasmania, 150 ; and Queensland, 250 different sorts. All told, the growth and behaviour of no fewer than 500 different sorts of wheat have been under examination by the different members of the Conference during the year last past. That the labours involved in these experimental undertakings are fruitful, and for the present full of promise of larger things in the near future, is shown by the facts given below respecting old-established and comparatively well-known varieties.

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By the use of new and unfamiliar sorts the list given might be greatly lengthened.

In all the five Colonies that have been represented at these Conferences the following varieties have enjoyed more or less immunity from rust attacks:—Improved Fife, Blount's Fife, White Fife, Blount's Lambrigg, Marshall's No. 3, Tourmaline, Pringle's Defiance, Fluorspar, Allora Spring, Hornblende, Sicilian Baart, and the various Durums.

A like unanimity is shown in respect to the sorts which have most readily succumbed to the disease. This list, of course, is too long for reproduction here. It is sufficient to say that the most pronounced of these are the numerous prolific members of the Purple Straw family with, among others, the Golden Drop, Tuscan, and Velvet Chaff varieties, all connected by certain affinities, the most pronounced of which are a large cropping capacity under favourable conditions, extreme whiteness and plumpness, with a corresponding granular structure of grain indicating the presence of much starch.

One of the noticeable results of the labours of the Conference is seen in the present hopeful view of the situation—as to rust contagion—now taken by practical men. The number of persons who believe that complete immunity from rust in the wheat crop will be secured is, perhaps, as few as ever; but the existence of the feeling that the disease may be minimised or so completely held in check that the loss from it will be small, is now all but universal.

The obstacles to the final success of the work of the Conference and the nature of the obstacles likely to be encountered in the future are suggested by the following facts:—

(1) The varieties which suffer most from rust, among which the disease is most easily communicable, are the white, highly starchy, and often prolific sorts made familiar in the practices of Australian farmers.

(2) The sorts least susceptible to the rust disease, that are most strongly resistant thereto, are generally hard or horny in texture, and often, though not always, dark in colour.

(3) These really rich wheats are constantly discriminated against by Australian millers, whose machinery, it would appear, is inadequate to the work of successfully manipulating them, and who, to a certain extent, set the fashion in flours.

It has been brought to the attention of this Conference that varieties of wheat, which in America and Europe are accounted of first value, from which indeed a large part of the flour of commerce is made, and which in Australia have shown themselves possessed of great rust-resistant power, are here, by millers, placed so low in price that their cultivation is rendered unprofitable. It is incredible that these hardy, high-quality, red and amber wheats shall be forever excluded from Australian agriculture, that Australian farmers are doomed, as it were, to cultivate only those varieties which are whitest—*i.e.*, richest in starch—least nutritious, and which easiest fall prey to the rust disease. Surely it is only reasonable to expect, in view of the vast interests involved, that the efforts of this Conference, looking to a common understanding among farmers, millers, and the scientific men who have given direction to much of these experimental efforts, should be heartily seconded by all interested. We therefore, in this special manner, direct attention to the resolution given further on, which suggests an Inter-Colonial Conference

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of millers, producers, and scientific men for the consideration of the question of the milling qualities of rust-resistant wheats.

This Conference desires to emphasise the recommendations of previous Conferences of this series. The effect upon the development of rust of manuring, of treatment of seed, times of sowing and reaping, are doubtless, under certain circumstances, often considerable; but taking things by and large, they must be reckoned as trifling, compared with the influences of variety and time of sowing. We have shown conclusively, in the experiments of a series of years, that certain varieties of wheat are rarely, if ever, seriously affected by rust. Many other sorts, again, of a rust-liable kind, generally escape the rust when sown early, but suffer seriously when late seeding is practised.

The importance of distinguishing clearly varieties likely to suffer or escape the effects of rust contagion is recognised by the Conference in the appointment of a Nomenclature Committee, whose work in this connection is shown in their report herewith. Preliminary to the work of this Committee, the following classes have been made, in which to place the various wheats :—

First Class.—Rust-proof wheats, by which is meant wheats which will not permit the mycelium of rust to enter and feed on their tissues. Of such wheats there are no known examples.

Second Class.—Rust-resisting wheats, by which is meant wheats which in localities suited to their growth and under normal conditions resist either the entrance of the rust-mycelium into their tissues, or its subsequent growth and outburst. Of this class many examples are known.

Third Class.—Rust-liable wheats, by which is meant wheats which, under the usual conditions of growth, offer no resistance to the rust. Australian wheats now mostly grown belong to this class.

Fourth Class.—Rust-escaping wheats, that is to say, wheats which, like the third class, are rust-liable, but which, if sown at the proper time, ripen so early as to be ready for harvest before the rust of an ordinary season can prevent a paying crop.*

Of these four classes the most important are the second and the fourth. The characteristics of the second class—namely, the rust-resistant wheats, have been found by a thorough and close examination of many varieties to be as follows :—*First*, the possession of a thick or tough skin, so tough that, although the rust mycelium may enter the plant by means of the open stomata, yet it cannot break through the skin in order to mature and shed its spores, so that its further development is prevented; and, *second*, the presence of a waxy exudation on the surface of the plant similar to the bloom of fruit; this waxy covering when present about the mouths of the stomata prevents the rust mycelium from entering. Wheats possessing tough skins, and especially if possessing the toughness of skin in conjunction with the waxy bloom, may be grown under all conditions suitable to their normal growth without suffering seriously from rust. On the other hand, the rust-liable wheats which are characterised by the possession of a thin and tender skin, and often by the absence of bloom, can be grown successfully during

* Most likely a fifth class—namely, rust-enduring wheats—might properly be added.

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a rusty year only in one way, namely, by sowing at such time that the plant shall be for only a short period subject to the attacks of the rust fungus. As to the proper time of sowing such wheats no universal rule can be given. Sometimes these wheats escape rust the most when sown early and sometimes when sown late; but in the great majority of cases which have been examined by the Conference, early sowing has been very much the more successful. And when, in addition to early sowing, early-maturing varieties are selected, the loss due to rust becomes, taking the average of experiences, comparatively trifling. With these facts now clearly and indubitably established one may lay down a course of action which, if judiciously pursued, will certainly in great measure do away with the losses caused by rust. Thus there are many, perhaps the majority, of wheat-growing districts where, if quick-maturing wheats be sown early, they in nine cases out of ten escape damage by rust. If, then, the farmers in these districts, when they have the opportunity of sowing early, should sow such varieties as Steinwedel and Early Para, which are quick-growing wheats, or even such prolific wheats as Hudson's Early, Purple Straw, Talavera, or White Lammas, which, while not being specially quick-growing, are yet able to escape rust if sown early enough, they would run little risk of loss from rust. If, however, in such districts the farmer be prevented by late rains or other causes from early sowing, then he cannot sow this class of wheat without running serious risk. He should then on no account sow these wheats, but only those belonging to the class described further on as rust-resistant.

From the above it will be understood that the principal measure recommended by the Conference for dealing with the rust-pest is the growth of suitable varieties of wheat. But this is not the only measure that needs to be taken, for it has been clearly shown that varieties of wheat, both the rust-resistant and the early-maturing, are apt to change their character in the course of time, and, moreover, some of those varieties which are suitable in regard to their rust-resistance and early-maturing are unsuitable for general purposes owing to the possession of other undesirable qualities, and hence it is necessary that a thoroughly efficient and organised system should be established for the maintenance or improvement of the qualities of suitable existing varieties, and for the production and distribution of new and improved varieties, and at the present Conference a definite scheme of an inter-colonial character has been proposed and discussed and recommendations made for its immediate establishment. By means of this scheme the farmers will have distributed amongst them, time after time, as occasion may require, rust-resistant and rust-escaping wheats suited to their districts, the good qualities of which will have been ascertained and proved by a stringent test before distribution.

The question of the marketableness of certain rust-resistant wheat has been considered by the Conference. It has already been stated that Australian millers will not buy them except at reduced prices. Supposing such were the case, the evil would not be so great as that of the rust-pest, for it is obvious that a crop of 14 bushels to the acre of a rust-resistant wheat sold at 3*s.* 9*d.* per bushel would be a very much better return than a crop of 5 bushels or 6 bushels to the acre of a rust-damaged crop sold at 4*s.* per bushel. But some of the highest quality wheats of the rust-resistant class have been submitted to the judgment of leading millers, who have pronounced them to be of a good milling

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character. Many of the resistant wheats produce grain containing a greater proportion of gluten than do the rust-liable wheats, which contain, on the other hand, a greater proportion of starch. But that these hard and highly glutinous wheats produce good and nourishing flour has been shown by the Conference. Bread of good quality has been made from this flour, and there seems little doubt that such bread is more nutritious than that made from starchy wheats. Probably the best bread can be made by mixing both classes of wheat, as is now done in England. When the value of these hard glutinous wheats becomes more widely known in these Colonies, there is no doubt that a greater demand for them will spring up. In the meantime, however, it should be pointed out that there is already a large and constant market for the class of hard wheats—namely, the export market—and the principal condition necessary for the export of this class of wheats is that they should be grown in large quantities, that is to say, in shiploads.

In connection with the question of the market value of wheats, the Conference recommends that the Agricultural Department of each Colony should take steps to establish a system of testing wheats in the laboratory and reporting their value to the farmers.

In examining the varieties of wheat now grown in the Colonies the conviction has forced itself upon the Conference that, while in one of the great staple industries of this country—namely, that of wool-growing—the breeds of sheep are distinctly named, pedigrees kept, and the rules of breeding well known; in the other great industry—namely, that of wheat-growing—much confusion exists about varieties and their names, and much remains to be learnt in regard to the rules which should be followed in producing and maintaining varieties. Steps have, therefore, been taken in accordance with a resolution of previous Conferences for making a complete collection of all varieties now in the Colonies so as to compare them and decide upon a common system of names, and also experiments have been commenced for enlarging our knowledge concerning rules for improving the qualities of wheats and for producing new varieties.

For the purpose of formally embodying the above policy the Committee recommends that the following resolutions be adopted by the Conference:—

Recommendations for the Immediate Attention of Farmers.

1. In previous years this Conference has drawn attention under the head of "Recommendations for the Immediate Attention of Farmers" to certain practical rules of proved utility in checking the spread of rusts. These rules have come to the Conference as the personal experiences of individual members, and through correspondence with the practical farmers and wheat-growers of every section of the Australian Colonies. Like all rules of agricultural practice, these recommendations are not to be taken as infallible, nor are they offered as specifics for the disease which the Conference has been called to combat. They no more than represent certain well-marked and clearly defined tendencies. But, while it is true that the farmer whose practices conform to these recommendations may yet be a sufferer from the rust contagion, it is absolutely certain that he will suffer in a much less degree than his neighbour who in practice ignores these dicta of the Conference. In this respect the experiences of the past season but add force to those of previous years. The Conference,

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therefore, desires, without going to the length of repeating the rules laid down in the reports of the Melbourne, Sydney and Adelaide meetings, to re-affirm with slight modification the suggestions made in the reports of those meetings. Whatever other measures may be adopted by the farmers with the object of preventing the disease entirely or of arresting its further spread, the practices here suggested may not with safety be ignored. These recommendations, briefly stated, are as follows :—

I.—Early sowing and the cultivation of early-ripening sorts.
II.—Harvesting rust-infected crops in the early or "dough" stage.
III.—The growth of sorts which local experiences have shown to be rust-resisting or rust-escaping.
IV.—The growth of wheat after fallowing, or after crops of a different order, agreeable to the true principles of rotation.
V.—Thin seeding, with due regard to varieties and local conditions of soil and climate.

Prizes for Wheats at Shows.

2. This Conference recognises the need of an awakened interest in the new facts bearing on rust resistance, and believes that the agricultural shows may contribute largely to this object. We, therefore, urge upon local societies the importance of offering special prizes for collections of wheats of proved value as rust-resisters ; and it is further advised that these collections be kept separate from the general wheat exhibits, and that they be plainly labelled, to the end that a wide publicity be given to the general subject, as well as to the characteristics of promising sorts.

Trial of Various Wheats.

3. This Conference believing that no such cereal as rust-proof wheat has yet been discovered, but that, as shown from experiments lately carried out, by importing different varieties from countries outside the Australian Colonies, and by carefully selecting and crossing them within the Colonies, certain kinds have been found to constantly escape to a considerable extent the ravages of this pest, recommends a continuance of this work of importation, selection and crossing, with a view to securing varieties most likely to escape rust and specially adapted to the different districts of our Colonies. And it having been found from evidence submitted to this Conference that certain varieties of wheat, believed to be rust-resisting when grown in one locality, have succumbed to this pest when grown in another locality, this Conference considers that while it would not be justified in specifying any particular varieties as possessing rust-resistant qualities under all conditions, nevertheless particularly recommends the following in the order given as worthy of being grown on a large scale :—

A.—*Recommended for Growing on a Large Scale.*

I.—As rust-resistant—
(1) Blount's Lambrigg, (2) Leak's, (3) Belotourka,* (4) Ward's Prolific, Marshall's White, Canning Downs Rust-resistant, Marshall's 3, Marshall's 8, Defiance.

* Belotourka is specially recommended for hot districts, either in the interior or on the coast.

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II.—As prolific and moderately resistant—
Talavera.

III.—As rust-escaping if sown early—
(1) Allora Spring, (2) Early Para, (3) Hudson's Early Purple Straw, (4) Early Baart, (5) Velvet Pearl.

IV.—Quick-maturing wheats for late sowing—
(1) Allora Spring, (2) Velvet Pearl, (3) Canning Downs Rust-resistant, (4) Early Baart.

B.—*Recommended for further Trial on a Small Scale.*

I.—As rust-resistant—
(1) Fluorspar, (2) Blount's Fife, (3) Fultz, (4) Tourmaline, (5) Niagara, (6) Improved Fife, (7) Anglo-Australian or Anglo-Canadian, (8) Manitoba, (9) Square-headed Sicilian, (10) Sicilian Baart, * (11) Clarke's Rust-proof, (12) Hornblende, (13) Summer Club, D'Arblay's Hungarian, Australian Wonder, Bearded Herisson, Marshall's 4, 6, 7, Hercules, Marshall's 10, 11, 33, 36, 17, 23, 26, Battlefield, Marshall's Prolific, Thomas' Rust-resistant, White Fife, Wheaton's Rust-proof.

II.—As rust-escaping—
(1) Jacinth, (2) Quartz, (3) King's Jubilee, (4) White's Velvet.

Recommendations for Government Action.

4. RESOLVED.—That it is desirable that a practical system for the production and distribution of rust-resisting wheats suitable to different districts should be immediately established, and that this system should, subject to modifications needed by each Colony, be conducted on the following lines:—A central station for each Colony for the preliminary testing of new wheats introduced into the colony, for the production of new varieties by cross-fertilisation and by selection, and for the distribution of suitable wheats thus obtained to representative districts of the colony, to be there subjected to a sufficient test and, if necessary, fixed in their characters by farmers and others competent for the work, and that such wheats as pass satisfactorily this test should then be distributed to the farmers around in such a manner and by such agency as would be most suitable to the conditions of each Colony. This Conference desires to place on record its unqualified approval of the course adopted by the Government of New South Wales in establishing a central wheat station and encouraging a number of farmers to grow pure seed-wheat true to name on a commercial scale.

Nomenclature.

5. RESOLVED.—That in connection with the inter-colonial exchange of seed now being carried on, steps be taken to continue the work of an Inter-Colonial Nomenclature Committee, and that such Committee be composed as at present, *viz.*, Dr. Cobb (Chairman), Mr. Farrer, Mr. McAlpine, Professor Shelton, Mr. Marshall, and Rev. H. E. Thompson. That one or more delegates from each of at least three Colonies shall constitute a quorum for the business purpose of this Committee.

* Sicilian Baart is recommended for coast as well as for interior districts.

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Experiments.

6. The Conference re-affirms the desirability of continuing experiments and inquiries in directions such as were indicated at the Adelaide Conference. The subjects for investigation fall under the following headings :—

(*a*) The effect, as regards rust, of manuring.
(*b*) The effect of applying lime, salt, and sulphate of iron to the soil.
(*c*) Effect of different modes of cultivation.
(*d*) Effect and economical application of drainage.
(*e*) Efficacy of burning all straw, weeds, and other plants in the infected field, and of using other disinfecting agencies with a view to destroying spores.
(*f*) Relative value of rust-shrivelled and plump seed.
(*g*) Relative value of different varieties of wheat.
(*h*) Effect, as regards rust, of different times and modes of sowing.
(*i*) Effect of different times and modes of reaping.
(*j*) Investigations regarding plants that act as intermediary hosts, and regarding all plants that are affected by rust in the different Colonies.
(*k*) Investigations as to the earliest stage of wheat in which the fungus may effect an entrance.
(*l*) Investigations regarding any insects, such as the recently discovered grubs of a *Diplosis*, which feed upon rust-spores and may be instrumental in spreading the pest.
(*m*) Investigations in regard to the influence on rust of interchange of seed between suitable localities.
(*n*) The influence which the growing of seed in hot climates has on the early maturing of wheats.
(*o*) Investigations in regard to the effect of mixture of seed in the development of rust.
(*p*) Microscopical and chemical examination of varieties of wheat in order to discover the characteristics of rust-resisting wheats.
(*q*) That in expressing the rustiness of a wheat plant it is desirable to state whether the rust occurs on the flag, sheath, or stem ; and that the amount of rust in any of these localities is best expressed in terms of the amount of surface covered by the rust.
(*r*) Determinations of the particular kind of *Puccinia* affecting the crops in different districts and the damage done by each.
(*s*) Investigations as to the relation between the variety of wheat and the time of attack by the rust-fungus.
(*t*) Investigations to determine the presence or absence of the rust-fungus in the seed.
(*u*) Investigations concerning the ability of certain wheats to endure the rust disease without injury therefrom.

The Next Conference.

7. Resolved.—That it is desirable, in the interests of wheat-growing in Australia, that another Inter-Colonial Conference on the subject of rust-resistant wheats and their milling qualities be held two years hence under the auspices of the various Governments, and that such Conference be composed equally of wheat-growers, millers, and scientific

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Publication of Reports on Experiments.

8. RESOLVED.—That it is desirable that reports of the coming season's inquiries and experiments in each Colony be published by the respective Governments in the ordinary departmental publications, and that an inter-colonial exchange of these reports be effected in the usual way.

Brisbane; 28th March, 1894.

V.—REPORT OF COMMITTEE, FIFTH CONFERENCE.

App. C. v. This Conference proposes to inform the public of the progress of investigations bearing on the problem it has now in hand, and offers a statement of the conclusions at which it has arrived. The Inter-Colonial Conference on Rust in Wheat was originally convened by the Government of Victoria in 1891, and it was then thought desirable that, if possible, light should be thrown on the problem—

(1) by researches into the Life-History of the fungus causing the disease popularly known as rust;
(2) by a careful study of the different varieties of wheat;
(3) by a varied series of experiments in the cultivation and treatment of wheat;
(4) by compiling the experience of practical farmers.

In succeeding years Conferences were held at Sydney, Adelaide, and Brisbane respectively, and at each the experiments up to date were discussed, new facts were brought forward, and the problem gradually simplified.

To give some indication of the vast extent of experimental work which members of the Conference have conducted during the period that has elapsed since the first Conference adjourned, the following may be mentioned as some of the many subjects of experiments:—

(1) The relations of applied manures to the prevalence of rust.
(2) Effect of different systems of cultivation.
(3) The character of the flag and straw of wheat as influencing the spread of the disease.
(4) The extent to which the rust spores adhere to seed wheat.
(5) Microscopical, chemical and milling characters of wheat and baking tests of their flours to determine the relation of rust-resistance to other qualities.
(6) The relative merits of different varieties of wheat, especially their rust-resistant properties.
(7) The creation of rust-resisting sorts by cross-fertilization and selection.
(8) The relation of hardness and softness of grains to rust-resistance.
(9) The relative rust-resistance of plants from large and small grains.
(10) The relative yield from plump and rust-shrivelled grains.
(11) The relative earliness of crops grown from seed consisting of large and small grains respectively.
(12) The relative earliness of plants from plump and rust-shrivelled grains respectively.

(13) The relative germinating power of plump and rust-shrivelled grains. App. C. v.
(14) The effect on earliness of the application of different manures.
(15) Improvement in milling qualities by selection and crossing.
(16) The effect of fungicides applied by spraying growing crops.
(17) Influence of insects as carriers of rust spores.
(18) Determination of the particular kinds of rust affecting crops in different districts, their life-histories and their effects on the host plant.
(19) Effect in relation to rust of different times and modes of sowing wheat.
(20) The practicability of disinfecting and cleaning threshing machinery by means of live steam.

Reflection will show that all these lines of experiment have a direct bearing on the rust problem. Numerous other experiments having a less obvious but still fairly direct bearing on the question have also been made but are not recorded here. Most of these experiments are such that reliable conclusions cannot be reached from one year's work. Indeed many of them will require to be carried on through a period of years, but when results are available they will be published by the Department of Agriculture of the Colony in which the results have been obtained.

The Conference believes, however, that already great good has come from meetings held in past years and recognises with much satisfaction that farmers in the several Colonies now pay more attention to the varieties of wheat: that many sow at least a part of their area with rust-resisting sorts; that there is more desire to obtain wheats true to name, and that many of the suggestions or recommendations of former Conferences, such as the desirability of sowing early in the season and the selection of early maturing varieties of wheat are now being acted on widely.

The Conference recognises further that through its influence farmers in wheat-growing districts in these Colonies have a choice of rust-resistant varieties of wheat capable of giving good average yields and of good milling quality.

Of scarcely less importance to the wheat-growing interests are the indirect results of the labors of this Conference. It may be said with entire truthfulness that the important results shown by the experiments of the different Colonies as carried out by members of this Conference have given an impetus to wheat culture in several of the Colonies at a time when disease and low prices had brought the business of wheat growing into general disrepute. It has been shown in the course of these experiments that the Australian Colonies are very favourable to the growth, in great variety, of the best and most nutritious wheats. The experimental stations have been centres from which new and improved varieties have freely passed to wheat-growing areas in all the Colonies. In this manner the suitableness of different sorts to the varying conditions of soil and climate covered by these investigations have been demonstrated, and knowledge of the capacity of the country for wheat-growing extended. These and other results not altogether germane to the original purpose of the Conference have grown out of its deliberations.

A prominent obstacle this Conference has met with has arisen from the objections of millers to rust-resistant wheats, and the adoption of such varieties has for that reason been retarded. We recognise

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that the dislike of these millers for rust-resistant wheats, as such, has had legitimate foundation in the past: for a large section of such wheats—the one section, in fact, in which rust resistance is a prominent and normal characteristic, consists of the maccaroni wheats which from the inferiority of the colour of the flour they yield and from its relative deficiency in strength (although not in gluten) are entirely unsuitable for the making of attractive and light bread, while their excessive hardness causes them to be difficult to grind. Many millers have doubtless experienced disappointment and loss from purchasing these wheats. Such objections, however, are entirely inapplicable to the wheats this Conference is prepared to recommend to the farmers as rust-resistant; they are not maccaroni wheats but bread wheats, and possess none of the undesirable qualities which are attached to the maccaroni section of resistant wheats; many of them, in fact, belong to the very sections in which are the wheats from which the best Hungarian and Minnesota flours are made, and these flours are considered to be among the very best in the whole world. Dr. Cobb's examination also of the relative hardness of wheats grown at the Wagga Experimental Farm (which, by the way, possesses conditions of soil and climate which are very fairly representative of the great bulk of the wheat-growing country of New South Wales, Victoria and South Australia) shows that the wheats we are prepared to recommend are many of them even softer than those which the millers are recommending to the farmers, purchasing readily and grinding every day; while Mr. Guthrie's practical examination of them with a roller mill has shown that stronger, more nutritious, and as attractive flour can be made in as large quantity and with as little trouble from a given quantity of most of them, as can be won from the largest, whitest, and most rust-liable wheats the millers view with approval.

The opinion this Conference has long held is, that the opposition of millers to such wheats has no legitimate foundation, but arises either from misconception or from conservatism; for the reasons which have been given above this opinion has become a conviction, and this conviction the Conference wishes to make public in this report with emphasis and without reservation.

The Conference considers the continuance of the work of the Nomenclature Committee of much importance, and especially that portion of its work which deals with the grouping of varieties of wheat according to the degree with which rust is resisted. No rust-proof wheat, properly so called, has so far been shown to exist, but there is no doubt that wheats vary very widely in their liability to rust. The terminology hitherto adopted has been found very suitable, and it is thought well that it be maintained and that wheats be grouped as follows:—

I.—*Rust-resistant Wheats*, such as Defiance and Ward's Prolific, which resist either the entrance of the mycelium into their tissues or its subsequent growth and out-burst.

II.—*Rust-escaping Wheats* such as Allora Spring, Early Para and Early Baart, which, though rust-liable, yet when sown early or in good time, ripen before the season is sufficiently advanced for rust to be propagated rapidly.

III.—*Rust-liable Wheats*, such as Golden Drop, Red Straw and Purple Straw, which very readily succumb to rust.

The wheats grouped in the first class are characterised (1) by the thick or tough skin of the plant—so tough that, although the rust mycelium

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may enter the plant by means of the stomata, yet it cannot break through the skin in order to mature and shed its spores, and accordingly its further development is prevented, or (2) by the presence of a waxy exudation on the surface of the plant similar to the bloom of fruit, which when present about the stomata prevents the rust mycelium from entering. Wheats possessing both these characters may be grown under all conditions suitable to their normal growth without suffering seriously from rust.

The second class of wheats does not invariably escape rust, yet the burden of evidence available to the Conference goes to show that in the majority of instances, if sown early, these wheats will escape serious damage. Even later wheats, such as Talavera or White Lammas, if sown very early, may escape rust in a season favourable for it.

The Committee with the suggestions of former Conferences before it, and in the light of new evidence and information which this Conference has elicited, recommends that the following conclusions and resolutions be adopted by the Conference :—

A.—*Recommendations to Farmers.*

Although no effective or unfailing means of preventing rust in wheat can be advanced, this Conference is of opinion that the risk of loss from the fungus may be lessened in a very marked degree by the general adoption of the following recommendations wherever practicable :—

(1) That early-ripening varieties be cultivated as extensively as practicable with reference to the exigencies of harvesting.

(2) That early sowing, more especially of the later sorts, be adopted whenever practicable.

(3) That early-sown crops be planted thinly with due regard to the habits of tillering of different varieties and the local conditions of soil and climate.

(4) That those varieties of wheat which experience has shown to be rust-resisting or rust-escaping, be grown much more extensively with due regard to market value.

In this connection the following wheats are recommended :—

(*a*) As *Rust-resistant.*—Ward's Prolific, Marshall's 3, Marshall's 8, Australian Wonder, Robin's Rust-resistant. For cooler districts,—Defiance wheats such as Wheaton's R.R., Blount's Lambrigg, Pringle's Defiance, Tunnack, Smith's Nonpareil. For cooler and moister districts, fine wheats such as Improved Fife and Hornblende.

(*b*) *Rust-escaping.*—Allora Spring, Budd's Early, Early Para, Canning Downs RR., Early Baart. When late sowing is inevitable, these wheats are very strongly recommended to be sown.

(*c*) *Prolific and Moderately Resistant.*—Talavera, Leak's White Lammas.

The Governments of the several Colonies represented at this Conference have a number of promising rust-resistant varieties under trial ; and are in a position to distribute to farmers, who may wish to test them, small samples of those which have given the best results. Farmers who are able to try new sorts are recommended to do so, and to make application to the Government of their own Colony for small samples of sorts which have given specially promising results in it.

(5) When sowing is unavoidably late, not only should early varieties be used, but these should be accompanied by phosphatic

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manures in order to hasten the maturity of the plant and lessen the risk of rust, as well as to increase the yield.

(6) That a change from the Purple Straw wheat, now so generally sown, to wheats of the White Lammas and Talavera types, more especially in the Colonies of South Australia, Victoria, and New South Wales, is desirable.

(7) Whenever large quantities of foreign wheat are available for seed from a climate differing essentially from that of these Colonies, it is considered hazardous for farmers to sow them on a large scale, however desirable it may be to sow them on a small scale for experiment.

The Conference further puts forward the following conclusions at which it has arrived :—

(1) It is of opinion that there is no possible treatment of the seed that will protect the plants growing from it from the attacks of rust.

Furthermore, that the notion that rust-shrivelled seed can be sown with as good results as plump seed is erroneous.

Of the many practical details which have been demonstrated experimentally as calculated to diminish the prevalence of rust, the Conference emphatically recommends the following :—

(*a*) That seed wheat be allowed to ripen fully and be carefully stripped or threshed.

(*b*) That seed wheat be graded and the larger and heavier grains selected for seed.

(*c*) That the utmost care should be adopted to ensure that the varieties of wheat selected for seed be pure and true to name.

B.—*Recommendations for Government Action.*

Seed Wheat.

Resolved.—That it is desirable that a practical system for the production and distribution of rust-resisting wheat suitable to different districts should be maintained and perfected, and that this system should, subject to modifications needed by each Colony, be conducted on the following lines :—Stations in wheat-growing districts in each Colony for the preliminary testing of new wheats introduced into the Colony, for the production of new varieties by cross-fertilisation and by selection, and for the distribution of suitable wheats thus obtained to representative districts of the Colony, to be there subjected to a sufficient test and, if necessary, fixed in their characters by farmers and others competent for the work, and that such wheats as pass satisfactorily this test should then be distributed to the farmers around in such a manner and by such agency as would be most suitable to the conditions of each Colony. *This Conference desires to repeat and emphasize its unqualified approval of the course adopted by the Government of New South Wales in establishing a central wheat station and encouraging a number of farmers to grow pure wheat-seed true to name on a commercial scale.* The results

which have already been secured in that Colony are such as to justify its emphasizing this approval. App. C. v.

NOMENCLATURE COMMITTEE.

RESOLVED.—That in connection with the inter-colonial exchange of seed now being carried on, steps be taken to continue the work of a Nomenclature Committee, and that such Committee be constituted as follows:—Dr. Cobb (Chairman), Mr. Farrer, Mr. McAlpine, Professor Shelton and Professor Lowrie. That one or more delegates from each of at least three Colonies shall constitute a quorum.

RESOLVED.—That in view of the desirability of the effective continuance of the work of solving the rust problem, it will be well that the work of the Nomenclature Committee be extended, and that to it be committed this task as well as that of from time to time making such recommendations to Governments of different Colonies as it, as a body, considers will advance the wheat-growing industry.

EXPERIMENTS.

This Conference re-affirms the desirability of continuing experiments and enquiries in directions such as are indicated in previous paragraphs of this report dealing with experimental work.

Melbourne, May 1896.

F. 725.

G. I. C. P. O.—No. 252 R. & A.—25-11-97—2,240

All communications regarding THE AGRICULTURAL LEDGER should be addressed to the Editor, Dr. George Watt, Reporter on Economic Products to the Government of India, Calcutta.

The objects of this publication (as already stated) are to gradually develop and perfect our knowledge of Indian Agricultural and Economic questions. Contributions or corrections and additions will therefore be most welcome.

In order to preserve a necessary relation to the various Departments of Government, contributions will be classified and numbered under certain series. Thus, for example, papers on Veterinary subjects will be registered under the Veterinary Series; those on Forestry in the Forest Series. Papers of more direct Agricultural or Industrial interest will be grouped according as the products dealt with belong to the Vegetable or Animal Kingdom. In a like manner, contributions on Mineral and Metallic subjects will be registered under the Mineral Series.

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